Interdepartmental Correspondence

December 14, 2000

To: Dr. Debra Friedman, Associate Provost for Academic Planning

From: Dr. Jeffrey Richey, Professor, School of Oceanography; PRISM PI

Please find attached the PRISM Progress & Planning Report for 1999-2000, project Year 3. In the spirit of preparing for the upcoming UIF review, we have attempted to provide a more comprehensive project overview than previous reports.

We believe that PRISM is going well and we are looking forward to working with you and the review committee to complete the program review in the coming months.

Cc: Arthur Nowell, Dean
Ocean & Fishery Sciences

University Initiatives Fund

Puget Sound Regional Synthesis Model —PRISM

1999-2000 Progress & Plans

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Year 3 Progress

The vision for PRISM was articulated in the original UIF proposal:

> As the Puget Sound Region moves into the twenty-first century, its managers and citizens will increasingly confront the task of making complex resource decisions involving natural variability and the effects of human alteration. The Puget Sound Regional Synthesis Model (PRISM) is proposed to simultaneously advance education and research within the University using Puget Sound as a focus, and to form partnerships and enhance cooperation between the UW and the Puget Sound community beyond the UW by:

- Creating and nurturing a Regional Synthesis, based on a "Virtual" Puget Sound
- Using this information and understanding as the framework for an Education Program
- Extending and applying this understanding for the long-term stewardship of the Region through a Regional Partnership with local government, resource agencies, regional education programs, and both public and private organizations

After the first three years of the program, this vision has not changed. We have maintained course and made significant progress towards our goals. We established Working Groups that are now the central mechanism for realizing these goals (Figure 1). The Working Groups are developed around the key model elements of the landscape and seascape that PRISM seeks to capture. Working Group membership is intended to focus expertise from the region, both internal and external to the UW. The status and plans for the working groups (which received explicit UIF funding) are summarized in Section II. The Budget for Year 3 is summarized in Table 1.

Year 4 Strategic and Funding Priorities

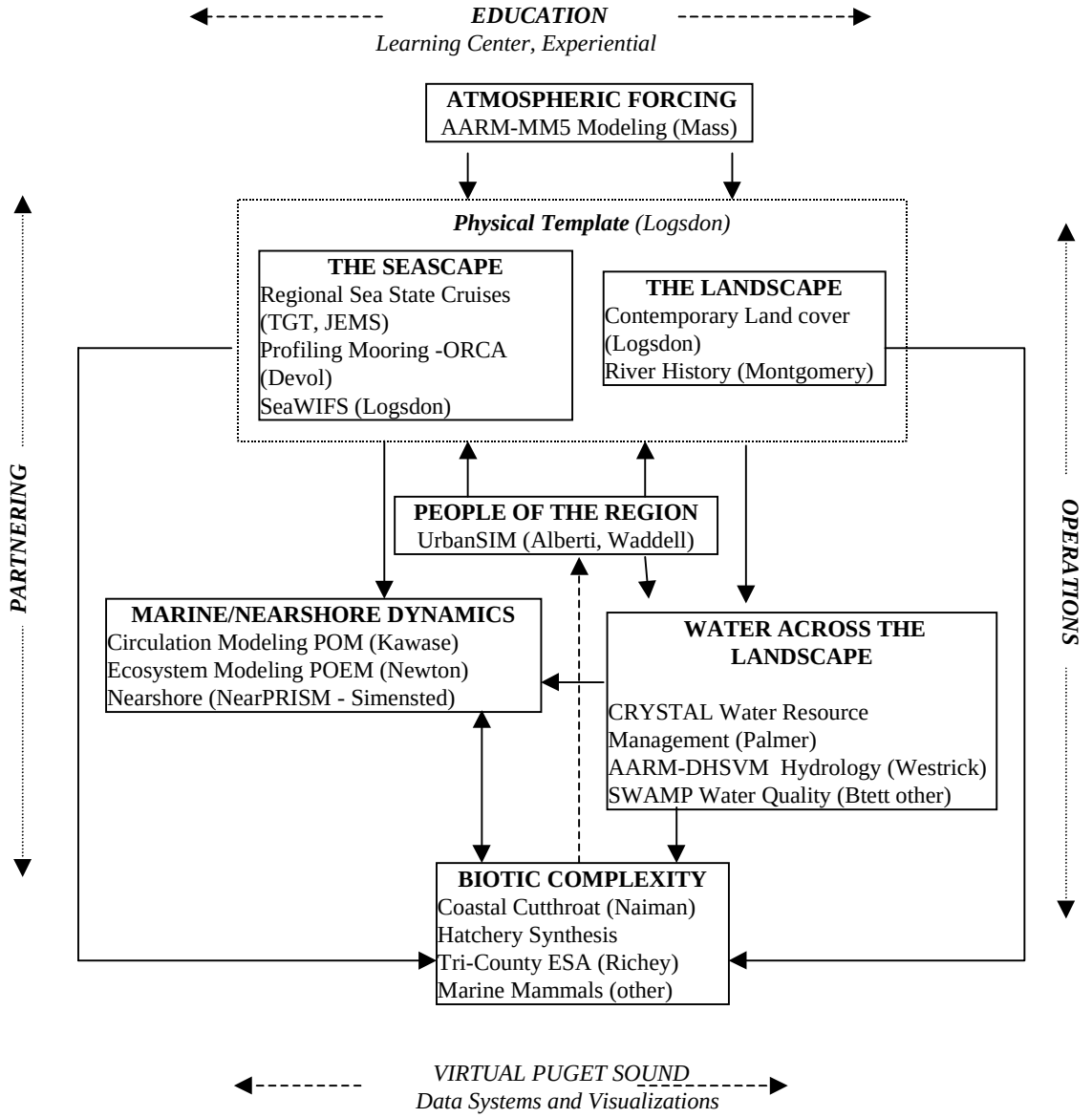
The strategy for the allocation of PRISM UIF resources is to fund activities that will:

- provide the strongest regional research role
- provide the strongest education impact possible, first at the UW then building to K-20
- consolidate its position of service within the UW on a long-term basis

Working Groups and Regional Impact

- Have the Working groups "mature" to where they adequately capture regional dynamics for the classroom and have the region invest in them both financially and programmatically. This will require the strongest possible communication within and between the working groups, within the UW and external to the UW. This communication should focus on the specific Partners who are or could be part of the Working Groups and getting specific tasks done.

Figure 1. PRISM Working Groups



- Fund-raising is essential, and must be focused on the Working Groups. While NSF-type grants are invaluable, Foundations and other significant regional sources are necessary. In doing this, it is very important to have an accurate representation of PRISM status, capabilities, intentions, and priorities to agencies and foundations. Limited UIF monies will be apportioned according to how closely the Group focus meets the overall needs.
- Implement (and fund) an externally-focused "PRISM Operational Group;" which can take PRISM information and make it systematically available to users on user time frames.

Education

- Use of Learning Center to:
  - Provide the maximum emphasis and support to the "Working-group" driven core courses (e.g.; Remote sensing classification, SWAMP, Drainage Basins)
  - Support of Puget Sound focus classes (e.g., Keil) Utilization and propagation of the Geo-Spatial initiative.
  - Summarize large forum classes (on a selected basis).
  - Support NSF Virtual Reality project.
- Strengthen POE ties
- Provide undergraduate research opportunities (experiential learning)

To take us into and beyond Year 4, a series of activities need to be accomplished:

1. The Steering Committee must work with the PI and the Operations Committee to solidify the exact direction of each Working Group. The PRISM portfolio and its regional implications will prioritize program resources. Each Working Group needs to evaluate exactly what is needed to keep and enhance its mission (mechanics, funding profile, integration with other groups, integration into the classroom).
2. In accordance with (1) the UIF monies available for Year 4 ($329,000) and the PRISM strategic priorities, the Year 4 budget (Table 2) is consistent with the above objectives, and comes with several provisos:
   - It is the responsibility of the PI to work with each Working Group on leveraging PRISM UIF funds.
   - As funding is found from other sources and UIF funding is replaced, resources will be reprogrammed within the entire PRISM program to best meet overall needs for a balanced budget target.

Table 1

PRISM UIF Year 3 Expenditures, 7/1/99 - 6/30/00		
Working Group/Project		
UrbanSim	$	112,617
ARRM	$	51,916
Physical Template	$	53,087
Puget Sound River History Project	$	18,513
CRYSTAL	$	38,775
Nearshore Modeling	$	10,444
Puget Sound		
Ocean Modeling	$	7,231
Ocean Mooring	$	40,087
PRISM Cruises	$	18,412
Learning Center	$	63,897
Aquatic Resources & Salmon	$	15,324
Program Operations		
Partnerships & Administration	$	74,179
Web & Course Support	$	45,672
Benefits	$	95,087
Year 3 expenditures total	$	648,241
Biennium 2 budget (includes $77,475 carry-forward from 1997-99)	$	977,475
Balance for Year 4 budget target		$ 329,234

Table 2

PRISM UIF Budget Year 4, 7/1/00 - 6/30/01		
Working Group/Project		
UrbanSim	$	39,185
ARRM	$	23,319
Physical Template	$	27,172
CRYSTAL	$	21,466
Nearshore Modeling	$	15,900
Puget Sound		
Ocean Modeling	$	3,840
Ocean Mooring	$	41,556
PRISM Cruises	$	11,150
Learning Center & Web Support	$	58,267
Program Operations		
Partnerships & Administration	$	47,974
Supplies & Equipment	$	3,000
Benefits	$	55,485
Year 4 budget total	$	384,314
Year 4 budget target	$	329,234
6% Budget deficit - will require reprogrammed funds	$	- 19,080

UrbanSim Project

The primary goal of the PRISM human dimension team is to develop an integrated model of urban development and environmental processes in the Puget Sound Region. We extend the object properties and methods now implemented in the UrbanSim model to predict three types of human-induced environmental stressors associated with urban development: land cover, water demand and nutrient loads. UrbanSim predicts the location behaviors of households, businesses, and developers, and consequent changes in land uses and physical development. These are among the inputs required to predict the changes in land cover and ecological impacts. Instead of linking the urban and ecological components sequentially, our strategy is to integrate them at a functional level and link these through a grid representation of land to infrastructure and natural systems.

Progress in 1999-2000

The main focus of the human dimension modeling team since August 1999 has been on implementing and testing the new architecture of the UrbanSim model to support microsimulation of the behavior of households, businesses, and developers and their spatially explicit interactions on a grid structure. We have redesigned and implemented two model components (land development and land demand) and are now developing specifications for the land cover change component.

We have made significant progress in developing the database required for implementing the UrbanSim model in the Puget Sound and five specific objectives have been accomplished in 1999-2000:

1. **Development of specifications for a land development model and an integrated strategy to specify the land cover change model**

A new specification of the land development model, based on the new grid infrastructure added to UrbanSim has been completed. Exceeding the original objectives for developing the specification of this revision, we have implemented the new specification in software as a new model component, replacing the previous deterministic model component. The new specification is a stochastic model, using a nested logit specification to predict that a cell will initiate a development event within a simulation year, and conditional on the choice to initiate an event, the probability that the event will be of a particular type. The model now deals with not only ‘greenfield’ development from vacant land, but also infill and intensification of development within cells that are already developed. Substantial ancillary development of tools for data processing and spatial query were necessary to implement the model. It has been tested with data from other regions while data for the Puget Sound region is prepared.

Based on the final form of the land development model specification, a strategy for extension of the model specification to deal with land cover change has been developed, and detailed specification and implementation of this component will follow as the next step in the model development.

2. Redesign of demand side and market interactions to reflect the new UrbanSim disaggregated structure from a zone description of space to one based on a high-resolution grid structure

The revision of the demand side components and market interaction has now been completed. We have respecified and implemented in software as revised model components residential location, employment location, and land price model components, all now based on the new grid cell infrastructure, and making heavy use of spatial queries within this infrastructure. The models have been tested with available data, pending completion of the local database. More specification testing will be done on local data as part of the local calibration of the model once this data is complete.

3. Implementation of grid structure and related changes in the UrbanSim architecture

The grid infrastructure has been completed, and required fundamental modifications to the architecture of all the model components as well as the data store on which the model operates. Spatial queries such as are commonly used in a raster GIS have been added to the model architecture, and used heavily in the revised land development, residential location, employment location, and land price models.

4. Creation of the database required to implement UrbanSim in the central Puget Sound region which includes land use, households, businesses, and infrastructure development

Land Use and Assessor's Data. Work from October 1999 through this date has focused on thoroughly developing the King County data set as a "pilot project" for the data development process. The bulk of that time was spent on reviewing and refining the parcel layer and processing the land use data. Data management and processing were challenging due to the large size of the data set (over 500,000 records) and inconsistent quality. Subsequently, additional attribute data from Assessor's records was compiled and referenced to the parcel layer. These data included: land and improvement value, number of residential and commercial/industrial units per parcel and the square footage of those units, and year built. A separate data set of bedroom counts was also compiled for possible future inclusion in the UrbanSim model. Initial work has now begun on the Pierce and Kitsap County data sets. The Pierce County data set on the land use coding is approximately 90% complete. The Kitsap County data is still in initial processing. Snohomish County is being held for last as currently only a subset of the County parcels have been made digitally available.

Land Cover. An effort to extend the land cover classification previously completed on the Puget Sound lowlands by Kristina Kill and Derek Booth has been completed to cover the entire study area. This work incorporated an improved version of the 1998 Landsat TM image (more thorough pre-processing). The accuracy assessment of the new land cover classification has also been completed. In addition, using the Puget Sound land cover extensive landscape pattern analysis work which will inform our land cover change model has been made using other research grants.

Additional land cover classification work has been the focus of Erik Botsford's Master Thesis on the development of a modified land cover characterization methodology. This approach utilizes ancillary datasets such as population density, employment and land use to modify the classification of spectral Landsat data. This hybridized land classification allows for the detection of a greater number of urban land character classes than can be identified using spectral data alone. This approach also introduces a functional aspect to land classifications that goes beyond land cover and incorporates variables related to land use types and intensities.

Study Area Grids. 150m and 1km grids of the study area (based on TAZ boundaries) have been developed to serve as a standard reference. Grid cell boundaries are located to coincide with the "official" PRISM grid.

5. Develop visualization architecture for UrbanSim model interface

A substantial effort to develop a visualization architecture has been made using other research grants, and is now operational. UrbanView links to the model architecture, and is implemented as a model component. It supports two dimensional and three dimensional mapping, and interactive rotation and perspective change. It also now supports the creation of small miniatures, or multiple views in small frames as a way to visualize multiple variables or time points simultaneously. Further refinement and user interface development is needed.

Publications

Refereed papers

M. Alberti, P. Waddell. An Integrated Urban Development and Ecological Model. Integrated Assessment. Forthcoming 2000.

P. Waddell. A behavioral simulation model for metropolitan policy analysis and planning: residential location and housing market components of UrbanSim. Environment and Planning B. Forthcoming 2000.

M. Alberti. Modeling the Urban Ecosystem: A Conceptual Framework. Environment and Planning B. Vol. 26, 1999.

Conference papers

P. Waddell and M. Alberti. Integrated Simulation of Urban Development and Land Cover Change. 4th International Conference on Integrating Geographic Information Systems (GIS) and Environmental Modeling, 2000, Banff, Canada.

M. Alberti and P. Waddell. Development of an Integrated Urban Development and Ecological Model. 6th International Conference in Urban Planning and Urban Management. September 8-11, 1999, Venice, Italy.

M. Alberti and P. Waddell. Development of a Land Use-Cover Model for the Puget Sound. International Conference on Land Use-Land Cover Modeling. IGB/LUCC. Honolulu, July 10-13, 1999.

1999-2000 PRISM Resources

RA Salary and tuition support for Erik Botsford, Leslie Pinnel, Gudmundur Ulfarsson, Michael Noth and Arun Lal; salary support for Alan Borning, Paul Waddell, Doug Pflugh; hourly support for Nathan Freier, Matthew Dockrey, Leo Lai, Michael Becke; travel and data purchase. .

Plans for 2000-2001

This year's work on UrbanSim will focus on completion of the local database; final specification of the environmental model components; and their implementation in software. Calibration of all the model components using local data will begin in 2000-2001 and extend into 2001-2002. Long-term, linkage to the travel model and macroeconomic model of the Puget Sound Regional Council is an important goal, as is user-interface development to ensure that the models are accessible and usable via the web.

In 2000-2001 we intend to accomplish three objectives:

1. Complete the specification and implementations of the three new modeling components: land cover change, water consumption and nutrient loads
2. Complete the Puget Sound land use and land cover database necessary for calibrating the model components
3. Develop a modeling forum with experts from various agencies to evaluate the new model design and implementation

Given funding limitations, we have prioritized Objective 1, completing the model specifications and implementation. Completing Objective 2 will depend on our success in obtaining additional funding from other sources. To complete Objective 3, we have begun a group process to involve experts from public agencies and the public in redesigning key model components.

PRISM Resources for 2000-2001

Funding for this effort is budgeted at on RA salary and tuition support for Michael Noth (CSE); two weeks of summer salary support for advisor Alan Borning (CSE); two weeks of salary support for Doug Pflugh for data synthesis; and $550 for LandSatTM data.

Plans for Leveraging the UIF funds

The size of the database for Puget Sound will likely exceed the capacity of the current memory-based architecture of the UrbanSim infrastructure, and will therefore require a change in the architecture to accommodate linking to a commercial database. This will be a fundamental change in the architecture that will require substantial effort.

A National Science Foundation grant for Reusable Modeling Components for Simulating Land Use, Transportation and Land Cover is supporting a significant expansion and improvement in the basic software architecture for the implementation of model components such as those we are constructing for PRISM. The grant will let us focus in PRISM much more on the design, specification, data collection, and calibration of the urban development, land cover, water

demand and nutrient emission model components. NSF is not specifically funding the development of those model components, but is funding the software architecture to facilitate development of such models.

A National Science Foundation grant for the Impact Urban Patterns and Ecosystem Dynamics is also supporting empirical research that will be critical to specify the land cover change model and further development of the UrbanSim model. This project has also provided support for assessing the accuracy of the Landsat TM image classification for 1998 that will be used in the urban pattern analysis and to establish a protocol for landscape pattern analysis.

We have also recently submitted a grant with King County for the EPA EMPACT program entitled Environmental Monitoring for Community Action in the Metropolitan Seattle-King County Region and Service Areas, US EPA. This project will be critical in supporting data collection and preparation for King County and provide a prototype for data fusion that could be applied to the other regions of the Puget Sound.

Atmospheric Modeling/Hydrology Working Group – AARM Project

Our PRISM work began three years ago, in 1997, as an effort to produce coupled riverflow forecasts for the Snoqualmie river watershed in western Washington (1,600 sq. km). Output from a mesoscale atmospheric model (MM5) was used to force the Distributed Hydrology Soil Vegetation Model (DHSVM). The initial configuration of the coupled MM5-DHSVM riverflow modeling system used 4-km resolution, hourly forecasts from the MM5 to create 36-hour riverflow forecasts. The riverflow forecasts were based on a hydrologic simulation of the land surface at a horizontal resolution of 150 meters. Initially, DHSVM employed a "unit hydrograph" channel routing method, so flow forecasts were only available at a single point within the watershed, the USGS gauge at Carnation on the Snoqualmie River. This system ran operationally through March 1998, but model output was only available for evaluation locally by the immediate PRISM research community. Evaluation of the four months of streamflow simulations revealed several deficiencies in both the model system and the static fields. It was also deemed essential to integrate an explicit channel routing method into the model system so that flow forecasting at multiple points within the river network could be accomplished.

In 1998, we integrated considerable improvements into the real-time riverflow forecast system during the summer and autumn quarters. Soil and land cover fields were improved and updated with higher resolution data, and we incorporated a variable depth soil model. Channel routing was upgraded to an explicit method (a linear reservoir scheme), allowing for the forecast of flow at all points along the channel network of a given basin. Due to these updates, the real-time system was expanded to encompass the entire Snohomish River Basin, which drains an area of nearly 4,000 km^2 of the western slopes of the Cascade Mountains in Washington State. The forecast period was increased by 12 hours by taking advantage of the 12-km resolution MM5 36-48 hour forecast output. An improved web site was created to allow forecasters at the Seattle NWSFO to access predicted riverflows. This system produced twice daily 48-hour riverflow forecasts for all 17 USGS gauge locations within the Snohomish River basin.

Progress in 1999-2000

Significant improvements in the operational system were incorporated during the past two years, from the summer quarter of 1998 to spring quarter of 2000. The real-time system has been greatly expanded during this time period and now encompasses nearly 15,000 square kilometers. Riverflow forecasts are generated twice daily for the 43 active USGS gauge locations in the Sauk, Stillaguamish, Snohomish, Cedar, Green, Puyallup, Nisqually, and Deschutes river basins. Analysis of riverflow forecasts during this period revealed the importance of generating hydrologic initial states that reflected actual observed conditions. To this end, considerable effort has been given to developing a framework for integrating available real-time observations of meteorology into an observations-based hydrological simulation to provide unbiased initial model states for each hydrologic simulation.

Unfortunately, experience has shown that these observations are seldom available in real-time and suffer from poor quality control. Therefore, the observations-based simulation has not yet provided a significant improvement in the reliability or accuracy of streamflow forecasts. As an

alternative, a framework for incorporating direct observations of relevant hydrologic states (e.g. distribution of snow cover and snow water equivalent over the forecast region) has been developed and will be tested operationally during water year 2001.

The hydrology model has also been modified to allow forecasters to input forecast Quantitative Precipitation Forecasts (QPF) directly into the model system. These values are then spatially interpolated over the basin using a method that incorporates the PRISM-derived climatological precipitation fields. A number of offline tools were developed to aid in the transportability of the hydrologic modeling system between river basins. These include a real-time visualization system and an offline method for optimization of the hydrology model.

Recent studies have shown that poor atmospheric initializations over the data-void eastern Pacific adversely affect forecasts. To aid in providing a range of forecast options, the Department of Atmospheric Science is currently developing and testing a capability for producing ensemble mesoscale forecasts for the region. The range of solutions provided by these ensemble forecasts provide a range of predicted hydrologic responses, thus providing the hydrologic forecaster more information for making a confident forecast. An operational framework that uses the atmospheric ensembles to produce ensemble forecasts of streamflow is currently being tested in the context of the real-time riverflow forecast system.

In addition to the increased capability of the real-time, coupled riverflow forecast system, considerable effort has been placed on upgrading the retrospective hydrologic modeling capability. Distributed hydrological models require accurate meteorological inputs in order to produce realistic riverflow simulations. Therefore, comprehensive software has been developed to access, quality control, and integrate a variety of different observational data sets into continuous records. Given both the temporal and spatial heterogeneity in meteorological fields in mountainous terrain, considerable effort has been placed on both the quantity and quality of the data. Continuous, one-hour resolution meteorological records for over 50 locations throughout western Washington have been created for the period 1977-present, and have been used for both (hydrologic) model calibration and validation. These high-quality data sets have also being used for retrospective studies to assess hydrological sensitivities to changes in land cover (i.e., logging roads, deforestation) throughout the region by Storck (2000). This meteorology record will be extended back to 1948 in the near future.

Research Collaborations

A number of other related research projects have grown from this work. For example, efforts to model a recent flood event highlighted the shortcomings in both the rain gauge network and the WSR-88D radar derived precipitation estimates. The hydro-meteorological modeling and forecasting effort is also taking advantage of several other research projects being conducted throughout the University of Washington. For example, results from MM5 verification have been used to improve predicted precipitation, wind and temperature fields used to create the riverflow forecasts. Methods derived from the retrospective hydrologic studies and analyses have been integrated into the real-time system.

Educational Outreach

Another collaborative activity has been the creation of the Ferry Weather web page, which takes sensor data on Washington State ferries and coastal land stations, and presents surface weather over the marine areas of western Washington. This page reveals, for the first time, many of the features of the wind and temperature field over Puget Sound. It is can viewed at: http://www.atmos.washington.edu/~maciver/Observations/Ferry/Ferryjs/mainframe.htm

Publications

Storck, P., Trees, Snow and Flooding: An investigation of forest canopy effects on snow accumulation and melt at the plot, stand and watershed scales in the Pacific Northwest, Ph.D. Dissertation, University of Washington, 200 pp., 2000.

Westrick, K. J., C. F. Mass, and B. A Colle, The limitations of the WSR-88D Radar Network for Quantitative Precipitation Measurement over the Coastal Western United States, Bulletin of the American Meteorology Society, Vol 80, No. 11, pp. 2289- 2298, 1999.

1999-2000 PRISM Resources

Salary support for staff scientist Ken Westrick; graduate RA salary and tuition for Pascal Storck; plus misc. supplies.

Plans for 2000-2001

Domain Expansion

At the start of water year 2001 (October 2000 to September 2001) we would like to expand the operational forecasts of streamflow, snow covered area, and snow water equivalent over the majority of Western Washington (Skagit, Nooksack, Dungeness, Hoh, Cowlitz, Chelasis and Skokomish River Basins) and a single basin in Eastern Washington (Methow River Basin). Currently (May, 2000) the Skagit and Skokomish River Basins are close to operational. This expansion and the techniques developed to facilitate it, have represented a major focus of recent and PRISM ongoing work.

Urban Watersheds

While the flood forecasting system has proven itself to work reliably over a variety of spatial scales that drain mostly undeveloped areas, the generation of streamflow forecasts on small urban and sub-urban streams is an area of increasing interest. The streamflow forecasting system is currently being calibrated to a variety of smaller basins along the lower Cedar River Basin. Once the system is operational, the retrospective data (described above) regarding meteorology and land-use change will be used to assess the impacts of development on this watershed.

Integration with observational assets

Research is still needed in a number of areas, arguably the most important being that of observations assimilation, especially for precipitation. The paucity of real-time gauges in data

scarce regions, combined with the inaccuracy of both radar and satellite-derived precipitation products in these regions, argues for novel approaches. A mix of in-situ, remotely sensed, and model produced meteorological fields will likely be necessary to provide the best solution.

Future incorporation of real-time precipitation observations will focus on two major networks:

1. **Radar**. Although radar is of limited usefulness for precipitation estimates in the mountainous areas of the region (Westrick et al. 1999), it can provide reasonably accurate estimates in many of the populated, lowland locations, such as Seattle and Portland. We will develop tools to allow the integration of radar derived precipitation estimates directly into the DHSVM model. The use of locally derived Z-R relationships and methods of eliminating radar blockage regions are some of the areas of planned research.
2. **Rain gauges**. The integration of real-time precipitation measurements taken from rain-gauges into both model predicted and radar derived estimates will be an important research question. It is essential to accurately determine both the type and amount of precipitation that has occurred, especially in many of the mountainous locations.

Feedback from DHSVM to MM5

Currently the operational output from MM5 is used to drive the DHSVM hydrology model. Based on the input from MM5, predictions of soil water content and snow cover are made in DHSVM and are used to translate total available water (precipitation from MM5 plus snowmelt from DHSVM) into runoff. While considerable effort has been given to producing the best initial states of soil moisture and snow in DHSVM, these hydrologic fields are not currently being used by MM5 for its atmospheric forecasts. For water year 2001, the use of DHSVM fields of snow cover to initialize MM5 for each atmospheric simulation will be explored. The success of this experiment will depend strongly on the expansion of DHSVM (or a limited version based on the land surface representation of snow cover) over all of Washington state and the quality of real-time observations of snow cover and water equivalent over the model domain to verify the predicted snow cover initialization states produced by DHSVM.

PRISM Resources for 2000-2001

Funding for this effort is budgeted at six months of 50% salary support for Ken Westrick and six months of 50% salary support for Pascal Storck.

Plans for Leveraging the UIF funds

The remainder of the salary support for the group is expected to come from a proposal to NOAA's CSTAR program; thus, there will be considerable leverage of PRISM UIF funding. It should also be noted that the PRISM work is made possible by the substantial infrastructure provided by the Northwest Mesoscale Modeling consortium.

Physical Template Working Group

This Puget Sound Digital Template (PSDT) working group was formed in 1997 at the outset of the PRISM project for the purpose of constructing a digital data framework that would integrate the various numeric models which would become the backbone of the PRISM integrated model. Our working group took on the responsibility of outlining the input and output requirements for each of the other identified modeling working groups and reaching a database design which would share data, between the various working groups. In this way our working group built, managed, and maintained the first version of our Puget Sound “digital template” and provided the bases for realizing one of the integrating themes of PRISM; the “Virtual Puget Sound."

Over the past three years we have used various interdisciplinary teams of PRISM researchers to accomplish data integration. Two of the most important teams were the Data Group (DG), and the Model Everything Group (MEG). The initial configurations for all subsequent PRISM modeling activities have been based upon the initial decisions of these two interdisciplinary teams. The PRISM digital template is based upon the Universal Transverse Macerator projection and the zone-10 coordinate system defined in the NAD-27 datum. This decision require the transformation of many base data layers in the MM5, DHSVM, and POM models, and set the initial data modeling requirements for the UrbanSim model. All subsequent datasets have conformed to this standard.

The digital template for PRISM was defined during the first year of the project to contain 80 individual data themes at 6 different spatial resolutions and 4 different temporal resolutions. Our work over the last three years has been to prioritize and then realize fulfilling those data requirements. Many of these data were already available and required nothing more than a collegial data share, while others either did not exist or were of unacceptable quality. Two examples best illustrate how the PSDT working group has addressed their task to fulfill data needs while addressing the educational and outreach elements of PRISM as well.

Progress in 1999-2000

One of the most central themes shared between all of the PRISM science working groups is the classification of the land surface in to a physical description of the surface material at a spatial resolution which informs the biophysical and social mechanics of the models. Before the PSDT working group lead this effort no such dataset existed. PRISM purchased 4 complete Landsat-TM multispectral image datasets, pre-processed the data for atmospheric and terrain correction and calibration and used this data in two undergraduate courses to produce a current hierarchical structured landcover classified data product.

At the root of the template concept of PRISM is the need for a static data theme which we have termed “seamless physiogeography”; or the coupling of the Digital Elevation Model (DEM) of the terrestrial environment with the Digital Bathymetery Model of seafloor elevation of the marine environment. Because each of these individual themes reference a different “zero” datum the datasets do not agree in 3-D space and the correction factor is not uniform in space because the datum is tied to a mean sea-level measurement which differs from tide station to tide stations.

The PSDT working group assigned two undergraduate students to develop an error correction surface for the Puget Sound shoreline which in effect "tilts" the Puget Sound approximately 3-meter along a north/south axis. This new data model has never been available before. The modeling method will be published in a technical report with the USGS and NOAA Coastal Service Center and the data made available through the digital library here at the University of Washington.

1999-2000 PRISM Resources

Salary and benefit support for 12 months .5 FTE for Miles Logsdon, Oceanography; Harvey Greenberg, Geological Sciences; Lisa Steubing, hourly from Computer Science & Engineering. Travel support for Miles Logsdon for conferences and ground truthing activities; IDL software liscense and supplies.

Plans for 2000-2001

With the initial success of the individual science working groups and the delivery of a shared digital template, the PSDT working group will focus on improving the quality and resolution of the dataframe, expanding the domain to include Canadian data and extensions on the boundary conditions of the template, documentation and distribution of the dataframe, and continued updates to current themes as data becomes available.

Domain, Resolution, Update and Completeness

Our current spatial domain for comparable shared data is limited to the basin as defined by a 30-meter resolution elevation grid assigning surface flow to a "mouth" at Admiralty Inlet before entering the Straits of Juan de Fuca. For the purpose of setting correct initial conditions and evaluation of cumulative effects, we need to extend the domain beyond this boundary to include the bathymetery and terrestrial elevations of both Washington and Canada. In addition, we will complete transition of our basin boundaries and surface elevations to the finer 10-meter resolution in the U.S. region of the basin. We will begin the definition of coastal basins and shallow water bathymetery from this finer resolution data. We intend to purchase a current set of Landsat-ETM Images for this summer (June/July 2000) once again classify the data as a classroom activity.

Data Management

An important task of our working group will be to oversee the meta-data documentation of our current and future data holdings. With the current limits on funds and the focus of the other science working groups on model development, our group will at most only "stay on top" of the current data and not let the problem of lack of documentation get worse. However, we feel that meta-data documentation is a key component of the future PRISM agenda. Some of the pending issues are:

- What is data is missing from our current database?
- What data would be available for general distribution?
- What data is proprietary

- What are the storage and archiving requirements?
- Should we use a central or distributed database?
- What are the security issues?
- Are there any legal liabilities regarding data products?
- Any there intellectual property issues?
- Are standard formats imposed?
- What is our meta-data process?
- What are our quality control and data validation programs?
- What are the data retrieval and conversion issues?

Geospatial Education in the Earth Sciences

A major success of PRISM in the UIF context has been PRISM's contribution to the approval and sustain funding of a program for a coordinated curriculum in GIS and Remote Sensing for the Earth Sciences here at the University of Washington. This newly approved program will coordinate the course work between five academic units within the earth sciences with a specific emphasis on the use of spatial data and spatial models in ecosystem research. The PRISM database will serve as a major "driver" for course work and training as will the development and extension of the current models. Our working group will be coordinating with the faculty in these units and making use of the Center for Environmental Visualization (CEV) Learning Center as a service to the educational mission of PRISM.

PRISM Resources for 2000-2001

We will continue to rely on a minimum funding base specific to this working group and organize our activities as an extension of a coordination with all other working groups. Salary support for this project will consist of 25% Miles Logsdon, Oceanography; 25% Harvey Greenberg, Geological Sciences. PRISM will also support purchase of raw Landsat image data.
Total budget = $27,170 plus benefits.

Plans for Leveraging the UIF funds

In 2000-2001 we will be submitting a proposal to the NOAA Coastal Service Center for funding the Landcover classification activities.

Puget Sound River History Project

The Puget Sound River History Project is developing an environmental history of Puget Sound Rivers to provide context and guidance for river rehabilitation and restoration efforts in the region. The project is using both archival sources and contemporary process studies to document and develop an understanding of the changes to riverine landscapes over the past 150 years.

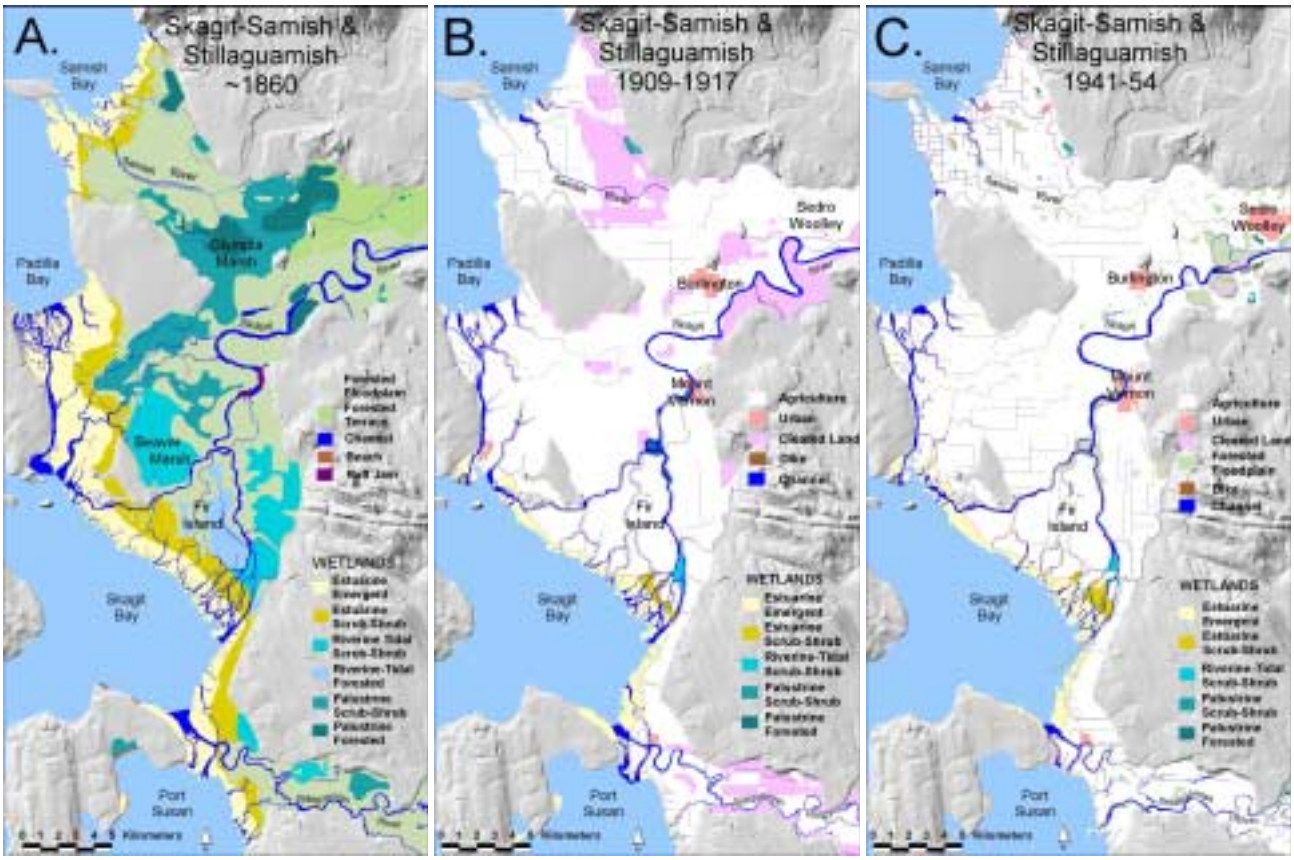


Figure 2. Historical riverine landscapes of the Skagit-Samish-Stillaguamish

Government Land Office surveyors notes from the 1860s – 1890s are being transcribed into GIS format and analyses based on these notes are providing documentation of habitat characteristics for the earliest time period for which quantitative reconstructions are possible. The geoecological effects of the documented changes are being investigated through process studies to help guide assessment of how to plan and evaluate river restoration efforts. In addition, the project is working with National Marine Fisheries Service scientists to evaluate the effect of historic habitat changes on salmon abundance in Puget Sound rivers.

The project has heavily leveraged PRISM funding through grants and contracts from external agencies. To date the project has focused on generating data and analyses from archival sources, and we expect to develop and expand web-based delivery of our results through PRISM. The project has finished analyses of the Skagit and Stillaguamish river systems and currently we are

working on completing historical analyses for all major river systems from the Nooksack to Nisqually Rivers. Summaries of some of our specific projects are included below.

Progress in 1999-2000

Forest development, log jams and restoration of floodplain rivers in the Puget Lowland

Brian D. Collins and David R. Montgomery

In Puget Lowland rivers historically, woody debris jams created anastomosing channels, a dynamic channel-floodplain connection, and deep pools. In the late 1800s, debris was removed from rivers, rivers isolated from floodplains, and floodplain forests cut down, thereby limiting debris recruitment. An 11-km-long reach of the Nisqually River is a unique site in the Puget Lowland to study natural river processes because it has natural banks and a mature floodplain forest.

The dynamic between floodplain forests, wood debris recruitment, and debris jams in the Nisqually shows that reestablishing floodplain forests and the fluvial processes that create stable log jams is integral to restoring Puget Low-land rivers. A critical question for contemporary restoration planning is how long it may take to reestablish debris recruitment and in-channel habitat. One necessary condition is for floodplain forests to include trees that provide wood debris large enough to function as key pieces in stable jams.

While the frequency of large trees in the Nisqually valley-bottom is comparable to that documented in 1873 land surveys, many of the formerly-dominant *Thuja plicata* (western redcedar) were cut down in the late 1800s, and now hardwoods, including *Populus trichocarpa* (black cottonwood) and *Acer macro-phyllum* (bigleaf maple), are also abundant. *Pseudotsuga menziesii* (Douglas fir) and the fast-growing *Populus trichocarpa* commonly form key pieces, suggesting that reforested floodplains can develop naturally-recruited stable debris jams within 40 to 80 years, much faster than generally assumed. A second necessary condition for restoring Puget Sound rivers is a dynamic river-floodplain connection to recruit enough debris to create jams. We propose a planning framework, based on these two conditions, within which to develop programs to restore self-sustaining, dynamic river morphology and habitat in Puget Lowland rivers.

Historic changes in the distribution and functions of large woody debris in Puget Lowland rivers

Brian D. Collins, David R. Montgomery and Andrew D. Haas

We examined changes in wood debris loading and functions in Puget Lowland rivers resulting from the last ~150 years of land use by comparing field data from an 11-km-long protected reach of the Nisqually River with field data from the Snohomish and Stillaguamish rivers, and archival data from several Puget Lowland rivers.

The field and archival data indicate that historic wood debris load has been reduced by one to two orders of magnitude. This is primarily due to a decline in wood debris jams, which are generally now absent because of a lack of very large debris that can function as key pieces, and

low rates of debris recruitment because of levees. The historic change in wood debris abundance and size fundamentally changed the morphology and habitat of lowland rivers at all spatial and temporal scales. Based on our field studies, rivers had substantially more and deeper pools historically. Archival data and field studies indicate debris jams were integral to creating and maintaining a dynamic, anastomosing river pattern with numerous floodplain channels and abundant edge habitat, and that wood debris routed floodwaters and suspended sediment onto floodplains and deltas. Targets for restoring rivers and habitat must take these historic changes into account.

Influence of landscape characteristics and land use on Coho salmon (Oncorhynchus kisutch) abundance in the Snohomish River, Washington State, USA.

George R. Pess, David R. Montgomery, E. Ashley Steel, Blake Feist, Robert E. Bilby, and Harvey M. Greenberg

Temporally consistent patterns in the spatial distribution of returning adult Coho salmon (Oncorhynchus kisutch) in the Snohomish River watershed, Washington, and correlative relationships between landscape characterstics and land use allows for the development of quantitative relationships between freshwater habitat condition and salmonid response. The extent of total Coho salmon abundance supported by a specific stream-reach or sub-watershed was constant, even though adult Coho salmon return levels varied by 300%.

Adult Coho salmon densities in forest dominated areas supported one one-half to three and one-half times the Coho abundance as rural, urban, and agricultural areas. Correlations between land use types and Coho salmon abundance were consistent over time. Wetland condition, geology, road density, and stream gradient were also significantly correlated to Coho salmon abundance. Spatially explicit Coho salmon abundance models developed explain less than half of the variation in adult Coho population size. The models do not account for factors beyond freshwater conditions that have a potentially greater effect on annual population fluctuations, but can be used to identify freshwater areas for protection and restoration.

Importance of Archival and Process Studies to Characterizing Pre-Settlement Riverine Geomorphic Processes and Habitat in the Puget Lowland

Brian D. Collins and David R. Montgomery

The synergy of archival investigations and field studies of protected rivers allows a quantitative, process-based, river-specific description of historic (pre-settlement) river landscape dynamics and sal-monid habitat in the Puget Lowland area, a landscape greatly altered by human activity in the last 150 years. While archival sources can document or suggest associations between landscape elements, they cannot demonstrate causality.

Field studies help to develop causal models, and archival studies, are necessary to capture intra-region variability in river morphology and process, that in turn determine where those models apply. Ergodic field studies also help illuminate smaller-scale processes that archival sources commonly do not de-scribe; only archival sources can reveal landscape-scale processes and features that no longer exist due to landscape alteration and fragmentation. In the Puget Sound region, this iterative approach demonstrates that, on a watershed scale, the preponderance of river and wetland habitat was in lowland river valleys.

Some rivers had an anastomosing pattern with many floodplain sloughs, in large part because of wood debris jams. Others had a single-thread meandering pattern, with oxbow lakes and vast floodplain wetlands. Estuarine marshes and channels were also extensive, but the amount and type varied with the rivers' different geologic histories. Wood debris formerly had a dominant influence on riverine processes at all scales; river restoration must emphasize restoring floodplain forests, the river's lateral erosion, and wood debris jams. The former abundance and diversity of lowland habitats also suggests the need to place greater emphasis on lowland restoration, and to consider such restored habitats as potential watershed refugia.

Research Collaborations

The Puget Sound River History Project has developed collaborations with the National Marine Fisheries Service (NMFS), King County, and the Nooksack Indian Tribe. The collaboration with King County and the Nooksack Tribe focus on historical reconstruction of riverine habitat characteristics based on historical sources for drainage basins of interest to these agencies. The collaboration with the National Marine Fisheries Service aims to extend this historical work and to support collaboration with NMFS scientists on analyzing the effect of documented habitat loss and land use changes on salmonid abundance in Puget Sound drainage basins.

UW Educational Activities

Dr. Montgomery co-taught (with Jeff Richey and Miles Logsdon) a PRISM course (GEOL 590) on drainge basin dynamics in Spring 2000. The course was co-listed between Geological Sciences and Oceanography.

Educational Outreach Activities

Based on the results from the project to date we are beginning to develop an internet presence to provide a watershed-based series of web pages that present both primary sources of historical materials and products derived from analysis of these sources.

Publications

To date the project has submitted three papers to peer-reviewed books and journals and has three more articles in preparation for submission in the near future.

Submitted

Collins, B. D., and Montgomery, D. R., Forest development, log jams, and the restoration of floodplain rivers in the Puget Lowland, submitted to Restoration Ecology.

Collins, B. D., Montgomery, D. R., and Haas, A., Historic changes in the distribution and functions of large woody debris in Puget Lowland rivers, submitted to Canadian Journal of Fisheries and Aquatic Sciences.

Collins, B. D., and Montgomery, D. R., Importance of Archival and Process Studies to Characterizing Pre-Settlement Riverine Geomorphic Processes and Habitat in the Puget Lowland, Geomorphic Processes and Riverine Habitat, J. B. Dorava, B. Palcsak, F. Fitzpatrick,

and D. R. Montgomery (eds). Water Science & Application Series, American Geophysical Union, Washington, D. C.

In preparation

Collins, B. D., and Montgomery, D. R., The Army Corps and the late 19th Century transformation of Puget Lowland rivers, for submission to Environmental History.

Collins, B. D., and Montgomery, D. R., The role of wood debris jams in mediating channel form and channel-floodplain interactions in Puget Lowland rivers, for submission to Earth Surface Processes and Landforms.

Pess, G. R., Montgomery, D. R., Feist, B. E., Steel, A. E., Bilby, R. E., and Greenberg, H., Influence of landscape characteristics and land use on Coho salmon (Oncorhynchus kisutch) abundance in the Snohomish River, Washington State, USA, for submission to Canadian Journal of Fisheries and Aquatic Sciences.

Proposals Awarded

The Puget Sound River History Project has leveraged our UIF support by securing $228,928 in external funds from from local, federal and tribal government agencies involved with salmon restoration.

Montgomery, D. R., Historic Reconstruction of Puget Lowland Habitats, Northwest Fisheries Science Center, National Marine Fisheries Service, 8/15/00-6/15/02, $60,360.

Montgomery, D. R., Historical Habitat Reconstruction of the Mainstem Snoqualmie River, King County, 9/15/00-12/31/00, $37,625.

Montgomery, D. R., Historic changes in geomorphic processes and salmonid habitat in the Nooksack River and floodplain, Nooksack Indian Tribe, 9/15/00 – 9/30/01, $72,021.

Montgomery, D. R., Interactions of floodplain forest, log jams, and channel dynamics in the Nisqually River: Implications for restoration and management of floodplain rivers in western Washington, 1/15/00-9/31/01, $48,922.

Montgomery, D. R., Habitat Loss in Puget Lowland Rivers, Bullitt Foundation, 7/1/99 - 6/30/00, $10,000.

1999-2000 PRISM Resources

Puget Sound River History Project salary and benefit support for Brian Collins, students Michelle Koppes and Amir Sheikh, Geological Sciences.

Water Resources Management – CRYSTAL Project

Progress in 1999-2000

The primary goal of the Water Resources Management Working Group is to create a framework that facilitates the evaluation of water resource alternatives based on their ability to supply water for both people and the natural environment (water for fish and folks).

Alternatives appropriate for evaluation include the development of new sources of surface water, water conservation, other supply augmentation options, expansion of current water transmission lines, modification of water pricing schedules, changes in water permits and alternative in stream flow requirements. Performance metrics associated with the outcomes of these alternatives require evaluation both from regional and individual utility perspective.

Four primary tasks have been addressed during the 1999-2000 period:

1. Refinement of the Cascade Regional Yield Simulation and Analysis Model (CRYSTAL)
2. Incorporation of long-term stream forecasts to improve long-term supply and drought management
3. Development of a regional optimization model of timing and financing of regional water supply components, including distribution system
4. Collaboration with other PRISM Working Groups to convert UrbanSim outputs into regional water supply demands

Refinement of the CRYSTAL Model

The group has modified several components of the CRYSTAL model to incorporate greater detail, provide increased operational realism, create new functionality and correct programming errors. Extensive work has been done on the Everett portion of the model to describe the current system as well as to run scenarios of interest to the City of Everett. This has included altering the model to allow exclusion of the hydropower component of model if desired, as well as other physical constraints associated with the Everett system. Much of this work has been accomplished working closely with Ken Howe of the City Everett and Bruce Meaker of SnoPUD.

We have continued to calibrate the model by developing contacts with specific water resource agencies in the region, including Seattle Public Utilities, Tacoma Public Utilities, Everett Water Department, King County, Snohomish County, Pierce County, and Snohomish PUD. The goal of this exercise is to receive regional acceptance of water supply and management models. A workshop of all major water supply stakeholders was held in May of 1999 to continue the education process with utilities. The team has also expanded the database upon which streamflows are taken. This resulted in extending the Everett input data from sixty-five years to 100 years. Tacoma data has been extended by four years.

The PRISM Model Documentation/User's Guide was finished and a web browseable version was incorporated into our web page. The documentation covers two facets of the CRYSTAL model. The first portion describes the user interface portion of the model, including comprehensive information about options a user may choose and a description of all components of the model. The second portion of the user's guide describes the three water supply systems depicted in the model.

Long-Term Stream Forecasts

In response to needs expressed by water supply managers attending the November 1999 Forum meeting, we have begun investigating the impacts of climate variability on water supply in the region. This investigation includes the characterization of streamflow and water supply during PDO-ENSO conditions. Thus far in the investigation, we have discussed this study with Seattle Public Utilities and the Army Corps of Engineers. We plan to evaluate the effectiveness of long-term forecasting (dependent upon climate conditions) on meeting instream flows and water transfers between Seattle and Tacoma. This study is designed after the work of Hamlet and Lettenmaier (1999) and will illustrate the impact of climate regimes on the probability of system failure and the ability to provide instream flows for fish.

Regional Optimization Model

We have begun development of a tool designed for use by water supply managers in the Puget Sound Region in regard to new water supply sources. The objective of this tool is to allow managers a robust yet user friendly tool that can evaluate potential water sources for development and recommend which source should be developed and when it should be developed to meet predicted demands. This tool will allow regional managers to improve regional water supply planning and operation. Criteria projected to be incorporated in the model include costs of development and operation (additional transmission lines, treatment plants, wells, etc.), environmental impacts (instream flows, wildlife impacts), projected demands, proximity to sources and political feasibility. The optimization tool will be independent of the input data. This independence will allow additional knowledge or data to be incorporated into the model as it becomes available.

We are currently in the data gathering and evaluation phase. Data are being collected from each utility regarding sources of water, future demands, transmission lines, and future water source options. Software and optimization methodologies are being evaluated. Several contacts have been useful in this phase. Bob Schwartz and Guillemette Regan of the Seattle Public Utilities, Kurt Myking of Tacoma Water Department, Brent Linder of the City of Everett, and Diane Robertson of RW Beck.

Regional Water Supply Demands

The group has moved to incorporate the most recent water demand data into the model. A recent report has updated regional water demands and these demands are being placed into the model. We have also evaluated potential incorporation of UrbanSim demand forecasts into our model. We determined that this was not currently feasible. We will continue to explore with Marina Alberti the use of forecasted water demands from UrbanSim as they become available.

It is important to note that considerable regional resources (outside of PRISM) have been devoted to evaluating the quality of local water forecasts. Because of this, it will be difficult to use any demand scenarios not based on the techniques developed by the Water FORUM.

It is anticipated that further development of CRYSTAL and its application will highlight deficiencies in the water supply planning and development process. The tool will ultimately help in the development of an integrated water supply strategy and possibly suggest the need for new methods of resource planning.

Research Collaborations

Throughout this year, we have continued our collaboration with the utilities to evaluate the model as well as add to it. This includes contact with Snohomish PUD (Bruce Meaker), Army Corps of Engineers (Marian Valentine and Linda Herman), and Seattle Public Utilities (Joan Kersnar and Alan Chinn).

Educational Outreach

- The Water Resources Working Group held a regional water supply modeling workshop in Autumn 1999 that had very good representation from local utilities. This was part of an effort to inform regional water supply managers of the PRISM project and its future directions. We also gained insight into what they would be interested in as components of CRYSTAL.
- In the Autumn Quarter of 1999, we organized and led a formal presentation to a subcommittee of the Water Forum to educate the group about the work of PRISM.
- The CRYSTAL model was used to generate information for the City of Everett concerning its water supply plan. The group drafted a water system "Safe Yield" report based on this data for the City.

Publications

Refereed Papers

Nelligan-Doran, S.E., Palmer, R.N., and Groome, A.R., Evaluating the Benefits and Costs of Responses to the Endangered Species Act on Water Supply Systems in the Puget Sound, Accepted subject to Revisions, American Society of Civil Engineers Journal of Water Resources Planning and Management, May 2000.

Reese, A.G., Palmer, R.N.,and Nelligan-Doran, S.E., Regionalization of Water Supply Systems: An Application in the Central Puget Sound Region, Accepted subject to Revisions, American Society of Civil Engineers Journal of Water Resources Planning and Management, 2000.

Conference Proceeding Papers

Groome, A.,Palmer R.N., and Nelligan-Doran, S., Potential Benefits of Water Supply Regionalization: A Case Study the Seattle and Everett Water Systems, Proceedings of the ASCE's 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management, Minneapolis, MN, August 2000.

Myers, A. and Palmer, R., Modeling the Impacts of the Endangered Species Act on Water Resources in the Puget Sound, , Proceedings of the ASCE's 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management, Minneapolis, MN, August 2000.

R.N. Palmer, Modeling Water Resources Opportunities, Challenges, and Trade-offs: The Use of Shared Vision Modeling for Negotiation and Conflict Resolution, Proceedings of the ASCE's 26th Annual Conference on Water Resources Planning and Management, Tempe, AZ, June, 1999.

1999-2000 PRISM Resources

RA Salary, benefit and tuition support for Amy Groome, Sherill Nelligan-Doran, Amie Myers and Sara Marxen; conference support and supplies.

Plans for 2000-2001

PRISM Resources for 2000-2001

RA salary, benefit and tuition support for Sara Marxen (Summer and Fall 00 quarters) and Amie Myers (Fall 00); additional RA support for Winter 01 quarter. Budget total = $21,466.

Nearshore Working Group - NearPRISM

The PRISM Nearshore Working Group (*NearPRISM*) is a newly formulated (9/99) working group that was assembled to address the scientific and technical gap in PRISM's linkages between watersheds and the surrounding land mass with Puget Sound. The broad **mission of *NearPRISM* is to develop information on estuarine and nearshore processes and environments that can be integrated into the emerging PRISM synthesis of the Puget Sound Basin**.

This will involve both spatial data on the structure of Puget Sound nearshore environments, and process information that will provide the interface between hydrology and other watershed processes and the Sound. This is NOT intended to be simply a unidimensional interface, however; our objective is to develop a functionally discrete nearshore "module" to PRISM that is characterized by unique attributes and processes that contribute to living resources, water quality, and the overall ecological integrity of Puget Sound. We propose to accomplish this as an interdisciplinary, multi-institutional working group composed of academic researchers and resource agency scientist-managers who will by their interaction keep water quality, natural resource and other management issues of Puget Sound foremost in consideration.

NearPRISM's objectives are to:

(1) assist in the design of an estuarine/nearshore model for PRISM;

(2) explore the development of an ecosystem-based assessment methodology for nearshore "functions" that takes into account physical controls on nearshore ecological and other processes that occur on landscape scales;

(3) evaluate and promote the acquisition of high-resolution nearshore spatial ("habitat" for the want of a better word) data that can be used in the PRISM nearshore model, the nearshore functional assessment, and evaluation of critical habitat for Puget Sound resources; and

(4) incorporate new information on transition of ESA-listed salmon from watershed to Puget Sound, and influence of habitat structure and anthropogenic alterations to shoreline or associated physical processes.

NearPRISM was initiated because the nearshore is interface of pervasive geochemical and ecological interactions that are presently lost in PRISM configuration of relatively unresolved boundary conditions of watershed and Puget Sound models. It plays a prominent role in integrity of some Puget Sound salmon stocks, and particularly so those that will likely be listed as threatened or endangered (e.g., summer chum and ocean-type chinook salmon). With the PRISM framework, there is a need to capture both upland/shoreline geophysics (sedimentology) and freshwater inflow influences on nearshore processes and function relative to anthropogenic alterations (e.g., changes in sediment sources and transport by bulkheading, groins, docks, etc., freshwater inflow of sediments, DOM/POM, pollutants, etc.).

We assembled the *NearPRISM* working group as a technical team composed of 10-12 scientists that will guide and implement the scientific/technical role of the Working Group. This presently represents UW PRISM faculty and researchers from the COFS and nearshore researchers and managers from three Washington state (Department of Natural Resources, Department of Ecology, Department of Fish and Wildlife) and regional (METRO King County) agencies, as well as consultants (Battelle Marine Science Laboratory). As the working group begins to develop more mature products, we will also assemble a larger (~25-30, but not necessarily restricted) advisory team that assists the technical team in directing its initiatives toward integration of estuarine/nearshore ecosystems of Puget Sound into PRISM that are meaningful to management and policy needs/issues.

Progress in 1999-2000

1. Six *NearPRISM* working group meetings since 9/99
2. Development of a conceptual model of nearshore processes as related to habitat structure (see Figure 3 below)
3. (PRISM) support (Sp Qtr 2000) of a QERM graduate student to assist NearPRISM in searching and evaluating the state of knowledge about characterizing and modeling nearshore physical-biological processes

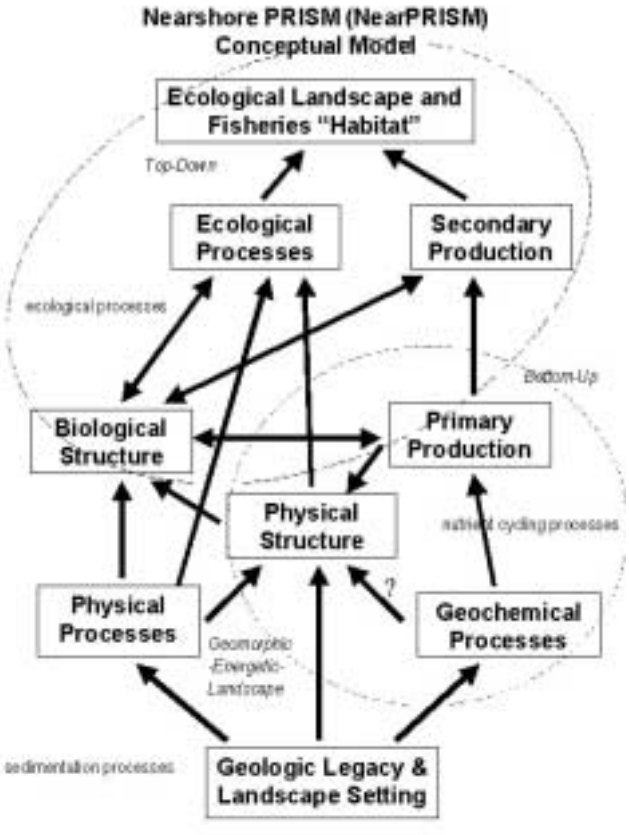


Figure 3. Components of conceptual model of linked nearshore physical and ecological processes along Puget Sound shoreline.

Proposals Submitted (now Awarded in Fall '00)

Proposal to Washington Sea Grant for support of a Ph.D. student to implement development of a numerical model

We proposed to develop a spatially-explicit dynamical model of sedimentation, geochemical cycling, primary production and habitat landscape change in Puget Sound's nearshore environment. The proposal addresses three fundamental needs that cannot be served by the more descriptive NearPRISM conceptual model: (1) need for a process model to guide future research needs and directions; (2) need for a predictive model to assess long-term, cumulative impacts of human impacts on the nearshore; and, (3) need for an effective, scientifically-based tool to increase understanding of dynamic nearshore processes by shoreline and resource managers. The project will:

- integrate this descriptive information into a spatially-explicit biophysical nearshore model,

- provide an interface between existing (PRISM) watershed and main (Puget Sound) basin models, and

- simultaneously integrate the expertise of resource management scientists into both the process of model development and education of students and agency personnel about estuarine and marine shoreline management.

- Ultimately, simulation of nearshore processes will allow the model to predict long-term, cumulative impacts of shoreline alterations, thereby guiding scientifically sound shoreline management.

The proposed Sea Grant project would support a Ph.D. graduate student, with guidance from key NearPRISM members, to integrate the emerging conceptual model into a functionally discrete, spatially-explicit nearshore module linked to the other PRISM models. Ultimately, simulation of nearshore processes will allow the model to predict long-term, cumulative impacts of shoreline alterations, thereby guiding scientifically-sound shoreline management. This project will provide graduate student support to assist in the integration of process models to simulate shoreline sedimentation with geochemical cycling of organic matter and nutrients, primary production, and the structure of fish and wildlife habitat over time based on spatially-explicit factors that delimit shoreline habitats such as mudflats, sand and gravel beaches, eelgrass, seaweeds and kelps. This nearshore biophysical model will be designed to link to watershed and marine dynamics models through the controls of freshwater inputs of nutrients, organic matter and sediments and marine ("offshore") exchanges of nutrients, organic matter, and organisms.

Seemingly representative of similar, inland seas around the world, little scientific research has been applied to understanding the interaction of physical, geochemical and biological processes in Puget Sound's nearshore, despite its economic and ecological resource value. As a result, resource managers and local governments lack necessary technical information to evaluate the cumulative impact of increasing modifications to

the shoreline, such as armoring, riparian loss, fills, and dock and pier construction. The proposed project would translate the NearPRISM conceptual model into a predictive tool for assessing the complex consequences of shoreline modifications. Direct, on-campus involvement of resource agency scientists in guiding model development will assure that the model addresses relevant issues and alternative approaches for management of Puget Sound shorelines.

The proposed project is new, and represents a critical step in a comparatively unprecedented initiative to address an emerging coastal management issue through a university-agency collaboration. The overall goal of proposed project is to generate a working simulation model designed to assess long-term cumulative impacts of shoreline modification that will have direct management applications. It is our intent to immediately and directly involve shoreline and resource managers in both the development of the model but also as conduits for education and training. On-campus involvement of resource agency scientists in guiding model development will assure that the model addresses relevant issues and alternative approaches for management of Puget Sound shorelines. However, our results will not be unique to Puget Sound. We expect that this work will apply well to the coastal waters of Georgia Strait and British Columbia.

Regional Collaborations

Promote information transfer and potential coordination among COFS and other research activities in Puget Sound nearshore environs:

- High-resolution remote sensing of Hood Canal-eastern Strait of Juan de Fuca intertidal habitat ("landscape") structure as a function of shoreline alterations and geomorphology
- Juvenile Chinook responses to freshwater and estuarine habitat structure during migration from Lake Washington to Puget Sound through Ship Canal and Locks
- Development of ecosystem integrity metrics of estuarine wetlands
- Experiments and sampling to understand effects of WSDOT ferry terminal structures on juvenile salmon migration along Puget Sound shorelines
- (various) estuarine habitat restoration assessment

1999-2000 PRISM Support

RA salary and tuition support for Cynthia Cooper (QERM); salary support for Charles Simenstad (Fisheries). Travel expenses for conferences.

Plans for 2000-2001

1. Continued refinement of conceptual model
2. Simple numerical modeling (e.g., STELLA) of conceptual model components

3. Close interaction with PRISM's Puget Sound Food Web Working Group to enhance direct model linkages
4. Explore funding opportunities to further enhance formal development of nearshore physical-biological processes model; specifically, initiate discussions with USGS-Menlo Park scientists about collaboration in developing a proposal for nearshore sediment transport studies and modeling in Puget Sound
5. Seek funding for field "case study" that would facilitate parameterization and testing of emerging NearPRISM model(s)

PRISM Resources for 2000-2001

One quarter RA salary and tuition for graduate student; salary support for two months time for Charles Simenstad (Fisheries).

Puget Sound Dynamics Working Group

The primary goal of the Marine Dynamics Working Group is to gain a better scientific understanding of Puget Sound's marine waters, in terms of its physical, chemical, and biological characteristics and processes, that will be synthesized to assess issues such as circulation, what food-webs the Sound can and/or did support, what impacts it receives from climate variation and from human actions, and how this relates to regional planning.

Progress in 1999-2000

Primary areas that have been addressed during 1999-2000:

- **Observations**: our direct measurements of Puget Sound properties
- **Modeling**: computer models of key processes to understand mechanisms and to use for predictive purposes
- **Education & Outreach**: Involving students and public in learning about Puget Sound
- **Remote Sensing:** Using satellites to measure important ocean properties in the Sound.

Observations

PRISM cruises

To date, five cruises have been conducted under the auspices of PRISM. The cruises on the R/V *Thomas G. Thompson* sample Puget Sound at 39 stations from the Strait of Juan de Fuca to Southern Puget Sound, including Hood Canal and Whidbey Basin. Beginning in 1998, cruises have typically occurred in June and December, which allows for good student involvement (see #3, below) and covers the strong seasonal variation around the solstices. During 1999-2000 we sailed in June 99 (Kawase, chief scientist), August 99 (Newton, chief scientist), and December 99 (Warner, chief scientist). The extra cruise in August afforded the opportunity to catch the ship in California and sail in from the Pacific Ocean, through the Strait, and into Puget Sound. The data showed the importance of the influx of recently upwelled oceanic waters with low dissolved oxygen content into Puget Sound. This is an important feature to better resolve, since oxygen is a key water quality variable that can be affected by human-caused eutrophication (e.g., point and non-point nutrient inputs).

The data from the cruises reveal interesting dynamics on the variation of water properties in Puget Sound and how these appear to vary with ENSO. Dr. Warner has produced contour images of much of the data collected on these cruises.

JEMS line

The Joint Effort to Monitor the Strait (JEMS), is a collaboration between Washington State Department of Ecology, King County, Friday Harbor Laboratories, NOAA, Roche Harbor Resort, and PRISM, that seeks to provide data from the Strait of Juan de Fuca. The data are critical to understanding the variation in oceanic forcing and input to Puget Sound. In 1999-2000, PRISM funded the nutrient and chlorophyll analyses from this monthly sampling program for

three stations in the Strait. The data are posted via ftp. The data are required in order to set the boundary conditions for hydrodynamic modeling of Puget Sound, such as is being done by PRISM, King County, and Department of Ecology.

CISNet mooring (see also ORCA Report)

Funded by EPA, NASA, and PRISM, this CISNet (Coastal Intensive Site Network) project is to develop and deploy a profiling mooring with real-time data transmission of key physical, chemical, and biological variables. The mooring measures vertical profiles of the water column for oxygen, nitrate, chlorophyll, temperature, salinity, as well as having sensors for optical properties and currents. The plan is to develop and use the mooring for studying eutrophication issues in Puget Sound. The current mooring is being deployed in Carr Inlet (South Puget Sound).

Modeling

Hydrodynamic

Dr. Kawase has adapted the Princeton Ocean Model to Puget Sound. It is currently functional and documented on the PRISM web-site.

Biological/Chemical

A Working Group of approximately eight investigators from UW, Washington Department of Ecology, and King County are developing a model that is linked to the hydrodynamic model and measures the flow of inorganic nutrients, phytoplankton and zooplankton biomass, and other key variables. This effort, began as a class, Ocean 506B in Spring quarter 1999, (co-taught by Newton and Richey), and has continued as a discussion group during 1999-2000 coordinated by Drs. Devol and Newton. We have now produced a conceptual model (box and wire) and nearly all of the defining equations, variables, and inputs. The next step will be to code this into a modular, user-friendly model.

National Ocean Partnership Program (NOPP)

The NOPP project is a planning exercise to create a modeling “node” or center of excellence for Puget Sound. Under a one-year grant from NOPP to Dr. Kawase, investigators from UW, Department of Ecology, and King County are meeting to define a plan for a five-year effort with a full NOPP proposal to be submitted in December, 2000) to establish such a center. Work is being undertaken to identify clients and needs, gaps in expertise, and products. PRISM has supported this with salary support for match, including 2 weeks of salary each for Drs. Warner and Logsdon.

Remote Sensing

SeaWiFS

Under the direction of Drs. Logsdon and Perry, the SeaDAAS ocean color data processing software was acquired and over 250 daily images from the SeaWiFS satellite remote-sensing platform were acquired and processed to the phytoplankton standard data product. A monthly composite classified image was constructed from the daily images for the summer months of 1998.

Because algorithms for conversion of the satellite data to chlorophyll concentrations are not optimized for Case 2 (coastal) waters, Dr Perry's group is currently devoting effort to measuring colored dissolved organic material Sound-wide, in collaboration with Drs. Newton and Reynolds and Ecology's Marine Waters Monitoring program.

UW Educational Activities

Students on PRISM cruises

Each PRISM cruise on the R/V *Thompson* has involved a high number of undergraduate students (as many as 16) in the labor force for data collection. Students are trained in all aspects of data collection: operating sensors, taking samples, conducting analyses, data processing, cruise organization, etc.

Oceanography of Puget Sound at two campuses

This 400-level course was taught in Fall 99 by Dr. Keil and is being offered at the UW-Tacoma campus this spring by Drs. Greengrove (UW-T) and Keil. Students in both classes produced material for web-sites describing their field research and findings.

OCEAN 599 *Coastal and Estuarine Geophysical Fluid Dynamics*

This graduate-level course was co-sponsored by PRISM and offered at Friday Harbor Laboratories by Dr. Rhines. Students studied the region around the Strait of Juan de Fuca and Strait of Georgia.

Educational Outreach

Various presentations have been given on the mooring and the project by Drs. Dunne, Devol, Emerson, Newton, and Perry.

The data have been used in numerous talks and poster presentations by Drs. Kawase, Newton, and Warner at local and national scientific meetings. A student documented one of the cruises; a photo essay is provided on the web-site.

A recent article in the Puget Sound Action Team's "Puget Sound Notes" chronicles this highly positive learning experience

1999-2000 PRISM Resources

Ocean Modeling

RA salary for Amanda Babson; hourly support for Kevin McHugh. Software and hardware for modeling.

Shipboard Observations - PRISM Cruises

Salary support for Mark Warner (Oceanography); chemical analyses of water samples from PRISM cruises.

Plans for 2000-2001

- Synthesis of current projects: There are many observations but these will need better synthesis. For example, a difference in ocean input due to upwelling intensity variation detected in the JEMS data is assessed in the CISNet data and SeaWiFS observations and in the interannual differences seen in the PRISM cruises.
- Database development: The PRISM cruise data are on personal computers but not in a freely accessed system.
- Biological/Chemical model coding: The model equations must be coded and turned into a user-interactive model that will then be verified and calibrated with PRISM and other Puget Sound data.
- 100-level PRISM class: The education for Puget Sound marine science is targeted at the upper levels only. Curriculum should be developed for a wider audience.
- Bringing Puget Sound observations into classrooms: The deployment of the CISNet mooring allows for the concept that real-time Puget Sound data could be piped into K-12 classrooms around the region, akin to what is done in Hawaii with the NSF-funded Hawaiian Ocean Time-Series (HOTS) data.

PRISM Resources for 2000-2001

Ocean Modeling

Hourly support for undergraduate student.

Ocean Observations - PRISM Cruises

Salary support, 50% for one month, for Mark Warner (Oceanography). Chemical analyses for water samples for three PRISM cruises.

Oceanic Remote Chemical/optical Analyzer Project (ORCA)

The goal of the Oceanic Remote Chemical/optical Analyzer (ORCA) project is to develop a water quality monitoring system in South Puget Sound. ORCA is a combined effort supported by the EPA-NASA-WA State Dept. of Ecology and PRISM. This effort is being headed by Steve Emerson, Al Devol and John Dunne in Oceanography in collaboration with Jan Newton (WA DoE/Oceanography), Rick Reynolds (WA DoE/Oceanography), Mary Jane Perry (U. Maine) and Parker MacCready (Oceanography).

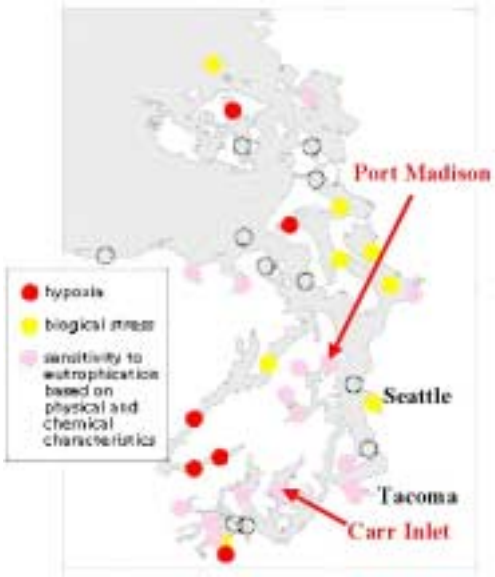


Figure 4. Data from the WA Puget Sound Ambient Monitoring Program (PSAMP) showing areas of severe (hypoxia), moderate (biological stress) and potential

Progress in 1999-2000

South Puget Sound is the most inland reach of Puget Sound with relatively sluggish circulation and seasonally stratification and intense phytoplankton blooms and nutrient depletions in the spring and summer months. With extensive urbanization of the area predicted for the next ten years, south Puget Sound is potentially at risk to impacts from eutrophication.

The purpose of ORCA is to use a variety of chemical and optical sensors enabling us to monitor tidal, diel, seasonal and inter-annual cycles and trends in stratification, oxygen, nutrients, water clarity and phytoplankton abundance and community distribution. ORCA provides a high resolution/long term data set for monitoring purposes, and allows us to test ecological and biogeochemical hypotheses about Puget Sound.

In addition to the mooring, itself there is a field component (Newton/Reynolds) for both verification of the mooring derived data and a broader survey of ambient conditions in Puget Sound. The project has a remote sensing counterpart (Perry/Reynolds) that will determine spectral qualities of Puget Sound waters. It is the intent that the mooring supply detailed time series data at one location. This mooring data combined with the survey data and optics data from the mooring location would allow extension of interpretations to greater Puget Sound through the broader survey and remote sensing data.

The Oceanic Remote Chemical/optical Analyzer (ORCA), as we have named it, is a technologically advanced aquatic observing system capable of profiling a sensor package through the water column to obtain high temporal and vertical resolution water quality data, and automatically sending that data back to the University. In it's present configuration, ORCA profiles every slack tide, monitoring pressure, temperate and salinity with a CTD along with chlorophyll fluorescence for phytoplankton biomass, water clarity and dissolved oxygen over the full 45 m water depth in Carr Inlet (Figure 4).

In 1999-2000, there has been great progress in developing ORCA. The first half of this year was spent primarily in the design, engineering, construction and software programming phase. There were a variety of profiling systems commercially available, but after investigating six such systems in the previous year and finding them all fatally deficient for our purpose, we decided to design our own.

We designed ORCA to be robust to sea-state and corrosion, to profile at high vertical and temporal resolution and to monitor meteorology, physical parameters such as temperature, salinity and velocity, chemical parameters such as nitrite, dissolved oxygen gas and dissolved total gas and bio-optical parameters such as irradiance, fluorescence and pigments.

The final design was based on the ocean-tested Atlas buoys used in the equatorial Pacific in the TAO-Triton array to study El Nino (Figure 5). On top of the Atlas float rests a platform with computer, winch, batteries, solar panels, cell-phone system and a superstructure with light and radar reflector. Beneath the float hangs a ballast ring that provides stability to wind and wave action. The system is designed for real-time communications and data download. The software driving the system is a C-code based in a large part on Charlie Erickson's (Oceanography/APL) glider project. The program is fairly sophisticated, taking the pressure data from the sensor package to run the winch and drive the sensor package through the water column, then uploading all the data from the sensor package and transmitting it back to UW for processing.

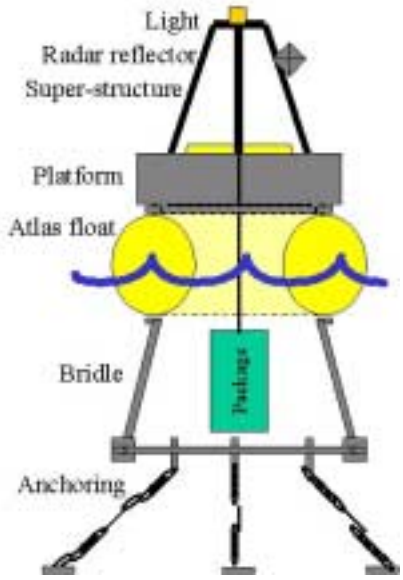


Figure 5: Schematic drawing of ORCA (Atlas float shown in cross-section).

The second half of this year was spent in the testing, redesign and deployment phases. There were many setbacks that had to be worked out in the electronic, mechanical and software components. For example, after failure of the cable winding system, the physical, power and communications tether between the sensor package and the winch, we were forced to redesign the winch twice. After failure of the cable itself, we were forced to change manufacturers and cable design.

The software has undergone - and continues to undergo - extensive improvements. The governmental permitting process has also taken much care; permits for mooring the buoy are required from many agencies. Pierce County Land Management oversees land usage. The WA Dept. of Ecology determines hazards to water quality. WA Dept. of Fish and Game determines hazards to fish and wildlife. The WA Dept. of Natural Resources owns the land. The US Army Corps of Engineers oversees the logistics of government land development. The US Coast Guard oversees usage of the waterway itself. All agencies differed in their responses, but each eventually agreed to accommodate us in mooring ORCA.

After a successful overnight deployment in Port Madison, Puget Sound (5/11-5/12), ORCA was moored in Carr Inlet on 5/24-5/26. We designed ORCA to be moored in a triangular configuration at the ballast ring with a system of chain to cable to chain to railroad wheels. This system provides extensive stability and security. This was an arduous undertaking for our research vessel the R/V *Barnes* as it was working near its limit to accomplish the difficult task of tri-moor deployment of such a large system. Due to the commendable efforts of skipper and crew of the R/V *Barnes*, ORCA was successfully moored in Carr Inlet.

Since its deployment, ORCA has been providing a near-continual stream of high-resolution water quality data from Carr Inlet. Color maps of the data illustrating the interplay between stratification, chlorophyll and oxygen are shown in figure 6. There is considerable variability in all parameters. Temperature and salinity force intermittently strong stratification. Oxygen and water clarity appears to undergo dual forcing from physics and phytoplankton activity.

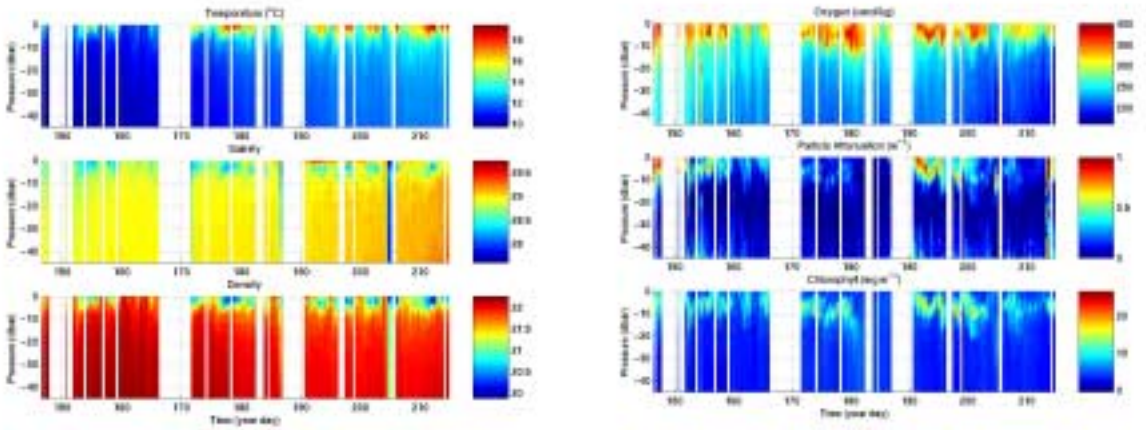


Figure 6: Color maps of temperature, salinity, density, dissolved oxygen, particle attenuation (water clarity) and fluorescence-derived chlorophyll for May 26th - July 25th.

UW Educational Activities

Over the last year, John Dunne has been involved with a number of education-oriented projects related to PRISM. John has been an active participant in the PRISM ecosystem modeling group that is developing an ecosystem model for Puget Sound. In this effort, John supervised a NASA summer undergraduate researcher named Neeta Bijoor who is implementing the model into the *Stella* and *Matlab* platforms as a first step towards incorporating biology and chemistry into the PRISM general circulation model. John also supervised Wendi Ruef, an undergraduate research technician, who developed a sampling scheme for our new nitrate analyzer that will soon be incorporated into ORCA. John has also been assisting in advising Julia Lynton, a graduate student working with Steve Emerson on the oxygen and total gas component of ORCA.

Educational Outreach

Last spring, John Dunne gave a lecture on water quality in the Puget Sound region to marine science students at Garfield High School. In addition, he developed a web page for the ORCA project for community outreach: http://www.ocean.washington.edu/research/orca

Regional Collaborations

Active intra-UW collaborations include those with the many members of the ORCA project as well as those in the PRISM ecosystem modeling group. Outside of UW ORCA has developed collaborations with many groups: WA Dept. of Ecology is providing calibration of ORCA data. King County Metro (Randy Shuman) is interested in applying this technology to monitor the new out-fall site. The US Navy Surface Warfare group at the Fox Island Acoustic Laboratory has assisted us in providing moorage for the R/V Barnes, advised us on some of the technical aspects of mooring in Carr Inlet. They hope to use the data we collect in assessing variability in the acoustic properties of seawater at their laboratory. The Monterey Bay Aquarium Research Institute (Ken Johnson and Thomas Chapin), who provided us with a prototype nitrate analyzer, are now working with us to develop it for high resolution profiling on ORCA. Seabird Electronics will soon be using us as one of their testbeds for a new oxygen sensor that they are developing.

Publications

John Dunne is currently preparing a manuscript for the Journal Marine Chemistry on this work.

Presentations

In September, John Dunne gave an information session for the King County Water Resources Division, the Washington State Department of Ecology and other interested parties.

In October, John Dunne presented a poster entitled, "Developing a profiler for Puget Sound: the oceanic remote chemical-optical analyzer (ORCA)" at the ASLO DIALOG conference (10/17-22/99) in Bermuda. This poster described the motivation development process and set of hypotheses that we hope to test.

In June, John Dunne presented a talk at the American Society for Limnology and Oceanography meeting in Copenhagen entitled, "An autonomous, moored profiler: the oceanic remote chemical/optical analyzer" which described the ORCA design, deployment and initial data set.

1999-2000 PRISM Resources

Salary support, 100% for 12 months, for John Dunne, Oceanography; engineering services for mooring construction.

Plans for 2000-2001

In the coming year John Dunne's plans for ORCA include: continue development of ORCA, maintain it, assure data quality through calibrations, continue developing ORCA automatic web data display, analyze the data and write it up. In its final configuration, ORCA will monitor nitrate, meteorology (air temperature, wind, humidity, light), underwater light, total gas pressure, spectral optical attenuation and scattering, currents. ORCA will also have the capacity for addition of other sensors as the need arises.

The sensors require regular maintenance to prevent biofouling and signal drift. John Dunne is now developing the computational framework for manipulating, analyzing and calibrating this data for automatic web display using a combination of *Matlab* and *Seasoft* data processing for a variety of formats. Data analysis will be the most challenging part of this project. The complex biogeochemical variability of Puget Sound is already revealing itself (Figure 3).

PRISM Resources for 2000-2001

Salary support, 100% for 12 months, for John Dunne (Oceanography).

Coastal Cutthroat Trout Project

Progress in 1999-2000

This project was completed by Joshua Latterell under the supervision of Robert Naiman and a Graduate Advisory Committee including Robert E. Bilby and Paul Bentzen. Contributors included: USDA Forest Service (PNW Research Station) Pete Bisson; PRISM, Jeff Richey; Weyerhaeuser Company (W. Timberlands Research), Brian Fransen; Center for Streamside Studies, Susan Bolton. Fish distribution surveys were conducted in 69 streams. Fish presence was detected in 52 of these sites (18 managed, 16 unmanaged, 18 pending classification). Fish have not been detected in 17 streams (5 managed, 12 unmanaged).

Preliminary Results

Reach-level constraints on fish distribution

The following reach-level habitat characteristics surveyed in reaches immediately upstream and downstream of the limit of salmonid distribution (i.e. non-fish-bearing and fish-bearing reaches): channel gradient, wetted width, bankfull width, reach type, pool characteristics (residual depth, length, width, formative structure), substrate characteristics (percent silt/sand, gravel, rubble, boulder/bedrock), LWD abundance, canopy closure.

Managed streams
(i.e. nearly entire drainage harvested once or more; in clear-cut to immature condition)

Weyerhaeuser Timberlands

Preliminary results suggest that steep channel gradient limits fish distribution on managed lands. Channel gradients were 7% greater in non-fish-bearing reaches ($p<0.000$). Canopy closure in non-fish-bearing reaches was 8% higher ($p=0.03$), and pool abundance was lower ($p=0.03$).

Federal and State Forests

Most of the sites surveyed in the summer of 1999 were previously harvested drainages under state and federal management. In these sites, non-fish-bearing reaches were characterized by steeper channel gradients ($p<0.000$), narrower wetted channel widths ($p=0.01$), and lower pool abundances ($p<0.000$). Wetted channel width may have been a stronger constraint on fish distribution in these sites, since these streams were sampled later in the year, when surface flows in some streams had begun to dry up.

* Data from these sites have not been included in the following comparisons of habitat characteristics in managed and unmanaged sites (pending land cover analysis)

Unmanaged Streams
(i.e. nearly entire drainage in mature and old-growth condition)

Federal Forest/Wilderness Areas

Preliminary results suggest that steep channel gradients are the strongest constraint on fish distribution in unmanaged drainages. Gradients in non-fish-bearing reaches were 18% greater in

slope than fish-bearing reaches ($p<0.000$). Lower pool abundance ($p=0.004$) and a higher proportion of boulder substrate ($p=0.01$) typically characterized non-fish-bearing reaches.

Comparisons of reach-level constraints across land use type (managed vs unmanaged)

The following are comparisons of the physical characteristics of both reach types (non-fish-bearing and fish-bearing) across managed sites and unmanaged sites.

Non-fish-bearing reaches

Non-fish-bearing reaches in managed sites were characterized by lower channel gradients and wetted width. Channel gradients in these reaches were 9% lower in managed streams ($p=0.05$). Pools were more numerous ($p=0.03$) and the proportion of gravel substrate was 20% higher ($p=0.04$) in managed sites.

Differences in channel gradients in non-fish-bearing reaches could potentially be due to differences in drainage morphology between land use types. Although I have attempted to select study sites in which the stream channel exhibits a smooth transition to high gradients, abrupt changes in channel gradient seem more common in unmanaged drainages. This could potentially prevent me from identifying subtle changes in the mean channel gradient at which fish distribution ends.

Fish-bearing reaches

In fish-bearing reaches, the only strong differences between managed and unmanaged sites were in the total length of pool habitat and proportion of pools formed by logs. Managed sites had less pool length ($p=0.10$) and fewer log-formed pools ($p=0.09$) than unmanaged sites. On average, we have captured more fish in the 100-m reach below the upstream limit of fish distribution in unmanaged sites than in managed sites. Preliminary results suggest that fish inhabit streams with similar channel gradient across land use type. However, cutthroat abundance appears to be higher adjacent to the limit of distribution in unmanaged sites.

Genetic sampling

In total, 257 samples from 26 sites (i.e. stream populations) have been collected. Species richness appears higher in managed sites, due to the higher incidence of cottids and introduced salmonids (e.g. brook trout, westslope cutthroat trout) within the study reach. These differences may also be related to locale or elevation. The catch-per-effort and total number of fish captured in managed sites has been approximately half that captured in unmanaged sites. We have also observed apparent hybrids between native and introduced salmonids. Genetic analyses will be used to verify the hybrid identification.

Challenges and concerns

Minimum detectable difference and sample size

Channel gradient appears to be the major factor reach-level factor limiting fish distribution and is an important parameter in GIS-based models being considered for implementation in Washington. Given the level of variance in channel gradient and a sample size of 30 stream

pairs, I have an 80% chance of detecting a difference in the gradient of fish-bearing reaches greater than 3 units (% slope) (where p=0.10).

Adding new reference sites from the Stillaguamish

We have been unable to find fish in a substantial number of wilderness sites. Many of the streams draining wilderness lands occur in valleys with narrow floodplains and steep walls. Some of these small, steep, often rocky drainages typically have little storage capacity and drain rather quickly. We often see evidence of substantial flows and well-defined channels in streams without surface flows. While the absence of perennial flows or fish provides information useful for basin-scale analyses of fish distribution, reach-level comparisons are less useful in streams without fish. In the interest of time, priority will be placed on finding suitable replacement sites with fish instead of measuring the habitat characteristics in the streams with no fish.

Most of the streams in the Alpine Lakes and Clearwater River wilderness areas are not suitable candidates for study. As result, most of the streams that meet my criteria and pair well with sites on managed lands have been surveyed. We were unable to detect fish presence in approximately half of those streams. To meet my sample size goals, new reference sites in wilderness areas have been selected within the Stillaguamish River basin. These low-elevation streams will pair well with managed sites on the Snoqualmie and Skykomish.

Last fish vs. last cutthroat trout

Although the Forests and Fish Report calls for a model that will predict the upstream limit of fish without regard to species, I think this project should focus on predicting the upstream limit of salmonids (especially coastal cutthroat trout) for several reasons. With the exception of bull trout, cutthroat appear to be able to use steeper, smaller streams than other fish found in headwater streams of the Puget Sound region. Therefore, a model generated from cutthroat distribution data would likely encompass the distribution of the entire local fish assemblage.

The location of the last fish (regardless of species) will be recorded in the field, but reach-level habitat surveys will be conducted at the location of the last salmonid to ensure comparability with Brian Fransen's fish distribution data. In streams where cutthroat do not occur, or when other salmonids occur farther upstream than cutthroat, we will survey habitat near the last salmonid rather than the last cutthroat.

Effects of fish stocking

Since the 1930's, many high lakes and sloughs in the area have been stocked repeatedly with native and non-native salmonids (coastal and westslope cutthroat, and brook trout). Stream plantings have occurred at a much lesser extent. To minimize the influence of fish stocking on the presence of fish and the location of the upstream limit of distribution, I have avoided all streams draining lakes in my site selection process.

The genetic landscape of cutthroat populations in the upper Snoqualmie basin is likely to be very noisy as result of extensive stocking activities in the area. Comparisons of genetic diversity in managed and wilderness populations may be confounded by the influence of this stocking. Whether these effects may be stronger in managed or wilderness lands is difficult to predict since easy access provided by logging roads may increase the incidence of stocking in managed lands,

but strong interest in creating recreational fishing opportunities has fueled the planting of many wilderness lakes. Westslope cutthroat may move out of lakes from which they were stocked and colonize nearby streams. This project presents an opportunity to characterize the extent of colonization by introduced populations and the extent of hybridization between stocked and native populations.

Changes in Methods

1-pass vs. 3-pass removals

In order to estimate the proportion of the population from which we obtain tissue samples for genetic analyses and to facilitate rough comparisons of population densities and assemblage composition, I had originally planned to conduct three-pass removal estimates of population abundance in all 100 m study reaches below the upstream limit of fish distribution. Since this sampling technique consumes the better part of a day to complete, only several streams will be sampled in this manner. These data will be used to estimate the proportion of the population captured in a typical 1-pass removal. For all other streams, the catch-per-effort (CPE) from a single electrofishing pass will be used as an index of relative population densities for comparisons between managed and wilderness sites. This requires the assumption of constant capture probability across paired streams.

Increasing genetic sample size

Cutthroat trout densities in the 100 m study reach below the limit of distribution have generally been too low to provide a suitable number of individuals for genetic analyses (~20). In response, I have started sampling a 200-m reach. Since there is typically a strong gradient in fish density over this distance in my study streams, separate CPE estimates will be calculated for each 100 m reach (0-100, 100-200 m from limit).

Funding

Joshua Latterell was awarded a $4,000 RASC Research Grant to fund the coastal cutthroat trout genetics component of this project. The UW Center for Streamside Studies graciously contributed one quarter of RA support.

1999-2000 PRISM Support

Salary support, 50% for six months, for Tom O'Keefe (Fisheries).

Plans for 2000-2001

- July 2000 — Field work
- August-September — Genetic analyses (Marine Molecular Technology Lab-UW)
- October-December — GIS modeling
- September 2000 — Papers submitted and thesis completed

PRISM Resources for 2000-2001

No PRISM resources are planned for this project in 2000-2001.

UW Hatchery Salmon Life History Data Synthesis Project

The purpose of this study is to investigate the trends within key life history traits in the populations of Coho and Chinook salmon in the University of Washington's hatchery. The UW hatchery has been in operation since the 1950's, and it is likely that changes in the salmon populations at this hatchery can provide insights into the ecology of Puget Sound salmon. This project was conducted by Jeramie Peterson under the supervision of Thomas Quinn and Vincent Gallucci in the School of Fisheries.

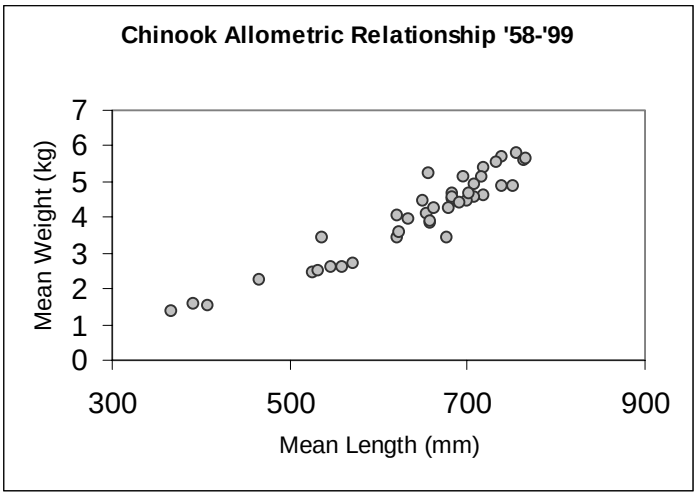


Figure 7. Length frequency distributions [LFD] for adult male and female chinook salmon

Progress in 1999-2000

The declines in abundance of Pacific salmon in the northwest and the application of the United States Endangered Species Act to Puget Sound in 1999-2000 have greatly increased the need to understand the changes in salmon populations in the region over the past decades. A balance exists between environmental and genetic controls over life history traits such as growth rate, age at maturation; timing of migration and maturation; and the size and number of eggs produced by females. The complex combinations of environmental and genetic factors affecting these key life history traits determines a species survival.

All key life history traits can be affected, directly or indirectly, by artificial propagation of salmonids in hatcheries. Growth rates are accelerated, compared to those in most wild populations, by feeding large quantities of nutritious food. The hatchery can also affect timing of maturation if they spawn all the early arriving fish and discard late fish once the capacity of the hatchery has been exceeded. Another example is that size-selective predation of eggs, common in natural systems, is eliminated in hatcheries and results in higher survival rates for offspring from small eggs relative to larger eggs.

UW Hatchery Background

In the early 1930's, while a graduate student, the late Lauren Donaldson conducted experiments on the growth and culture of salmon and trout at the UW campus. However, it was not until after the Second World War and his subsequent research on radiation ecology that Donaldson conceived and constructed a salmon and trout hatchery on the UW campus, and the first Chinook salmon were released in 1949. It was modified somewhat when a bulkhead was built, turning a cove in Portage Bay into a holding pond for adults in 1960, but has otherwise been structurally similar over much of its existence.

Coho (and sockeye) experiments in the early years were not very successful but starting in the late 1960's there were substantial numbers of Coho salmon returning, along with the Chinook. The stocks of Chinook and Coho salmon Dr. Donaldson used were primarily from the Green River system (Soos Creek hatchery), though some exchange with other populations took place over the years. Since the early days of the hatchery (late 1950s), all returning salmon were identified, measured for length, and weighed, and the date was recorded, along with any marks or unusual circumstances. For a large number of the females, fecundity (number of eggs) and egg size were also measured. This represents a priceless and unique record of salmon spawning date, size, and reproductive output in the Lake Washington basin. The detail of these records far exceeds that available for other hatchery or wild populations.

Analysis and interpretation of such data, collected in the past, was done cautiously. There has been a great deal of publicity regarding Dr. Donaldson's selective breeding of rainbow trout but the Chinook salmon also were also subject to selection, especially in the early years. Some degree of selection is common and perhaps inevitable in hatcheries, and it is unclear how much the phenotype of the population was affected by these efforts. We are relying on Donaldson's papers and those of his students, and the recollections of Dr. Ernest Brannon, who was Donaldson's Ph.D. student and supervised the hatchery after Donaldson's retirement in 1972, and Dr. Hershberger who supervised the hatchery when Dr. Brannon left the UW in 1988.

Data Status

When we first conceived the idea of assembling and analyzing the salmon records for the UW hatchery, the records of salmon returns and releases existed only in hand-written logbooks for all years until the mid-1980s. Some, but not all, of the more recent data were entered in computers but no analysis or interpretation had been undertaken. The first priority was to enter the raw data in a consistent and user-friendly format, and have them backed up in a secure manner. Progress to-date includes:

- almost complete transcription of data from the 1940s and 1950s to 1999 from paper files and reports to magnetic discs
- significant progress sorting, collating and filtering the data
- initial statistical analysis of some of the data.

In particular, Jeramie Peterson has been responsible for the transcription of the data from 1947 to 1999 on Coho and Chinook salmon smolts released from the hatchery. This includes data on the different treatments that were applied over this half century including temperature, nutrition, radiation and cross breeding of different return years. Jeramie Peterson has also been responsible for the transcription of return data including multiple biological parameters on size, reproduction and date of return. These data span 1957-1999 and the work was supervised by Drs. Quinn and/or Galluchi.

Selected Methods and Preliminary Results

Change in body size over time

Our goal was to test the null hypothesis (that body size has remained the same) against the predicted alternative hypothesis (body size is declining). In addition to looking at overall size trends, we have tried to look at size at a given age. Length frequency distributions [LFD] for

adult male and female Chinook salmon have been plotted as histograms for each year over the periods noted (e.g., Chinook salmon: Figure 7).

In addition to looking at trends in length and weight separately, we are also examining condition factor, the relationship between length and weight. It then becomes possible to infer the years during which lengths and weights were larger or smaller as well as when weights might be lower and lengths greater. These plots are being assembled at this time and represent a major present activity. Figure 8 (Chinook) is an example.

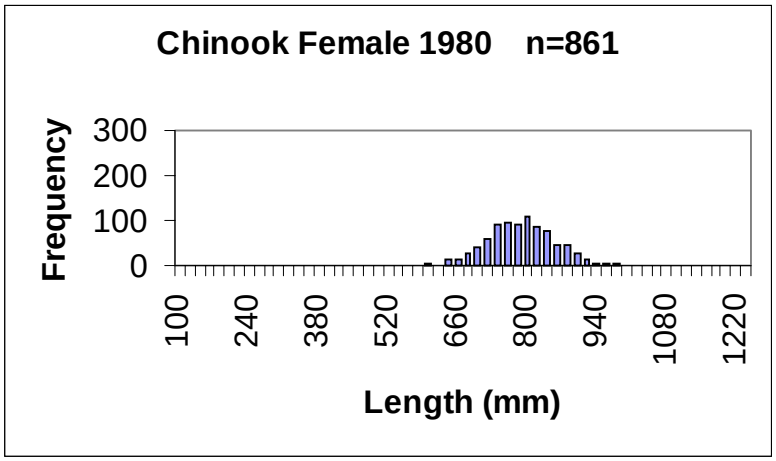


Figure 8.Chinook length 1980 UW hatchery fish

Fecundity and egg size

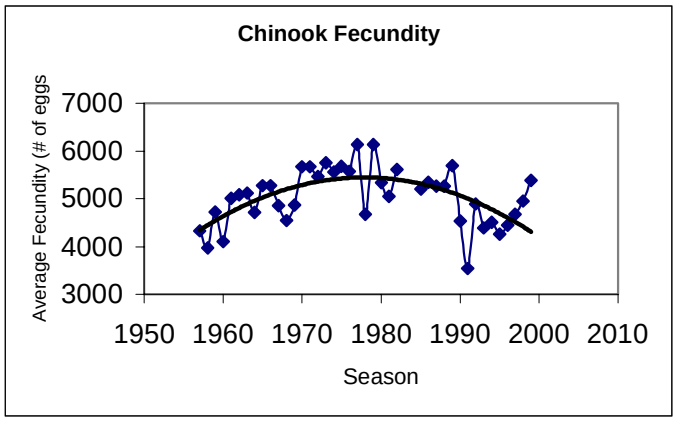


Figure 9. Chinook fecundity for UW hatchery fish

We are interested in the trends of reproductive output (egg size and fecundity) for female salmon over the years. Fecundity and egg size have been measured for a large proportion of the individual females (though some were measured as groups and some not measured) in a standard manner over the years, see Figure 9 (Chinook) for an example. We will also be looking at the relationship between egg size and fecundity for both species, and average fecundity and egg size for a given spawner size, to determine if the patterns of reproductive allocation have changed over the years.

Spawning Date

The purpose is to see if there are any changes in spawning date within the season. Based on anecdotal evidence, we hypothesized that that Chinook salmon are tending to spawn later and Coho salmon earlier than in the past. The mean and median spawn date for each year and for each species were calculated to determine approximately the time the majority of the spawning for each species occurred for that particular year.

Size at Release of Juveniles

The release statistics are less robust than those of the returning adults because individual fish are not measured. Instead, fish are weighed in bulk and counted to produce an overall average weight per fish but no variance. We will examine the interactions between release size and date, and associated patterns in returning adults (e.g., age and size at return).

1999-2000 PRISM Resources

Hourly salary support for Jeramie Peterson and Brandon Chasco (Fisheries undergraduates).

Plans for 2000-2001

Many aspects of the research described above need further investigation. A major step that will started Summer Quarter 2000 involves connecting the batches of released fish to those returning. There are several dimensions to this activity since a variety of treatments have been applied. For example, some released fish were treated with special temperature regimes, irradiation, nutritional adjustments and cross breeding of returned females with males of the same age, as would usually occur but also with males of younger ages who have appeared as jacks. Returns must therefore be culled to be sure that they are categorized correctly. In some cases, reports have been written and lie in the records, which need to be examined for their relevance.

Resources for 2000-2001

No PRISM resources are planned for this project in 2000-2001.

Learning Center Project

The current working group lead for PRISM visualization and interface development is the Center for Environmental Visualization (CEV). The mission of CEV is to develop educational interfaces based on environmental visualizations. Expertise at CEV includes the design and development of Virtual Marine Worlds, Scientific Illustrations, Environmental Web Sites and Interactive Visualizations. CEV has connections to the College of Ocean and Fishery Sciences, the Human Interface and Technology Laboratory and the College of Education.

Progress in 1999-2000

In 1999-2000 the Center for Environmental Visualization developed a new on-line Learning Center (http://www.cev.washington.edu/learning_center) while re-designing and maintaining the PRISM informational web site (http://www.prism.washington.edu). The PRISM informational web site has received 54,347 hits for the first quarter of this year (January - March 2000). The new Learning Center, still under development, had 6,586 for the month of April 2000, up from 3,261 for May. In addition to web development and maintenance, CEV also provided multimedia support for PRISM presentations and outreach as well as educational technology support for selected PRISM courses.

1999-2000 PRISM Resources

Salary support for Mark Stoermer (.33 FTE), Hunter Hadaway (.33 FTE), Bruce Campbell (.33 FTE) and Toby Latin (hourly). Supplies, printing, software, hardware and travel support for CEV. For network technical support, data management and web maintenance PRISM supported salary and benefits for Konrad Schroder, HITL (.20FTE); Jennifer Stone, Libraries (.10 FTE); Susannah Iltis, Fisheries (.20 FTE).

Plans for 2000-2001

In 2000-2001, the goal for this working group is to establish an on-line Learning Center as a collaborative resource for educators and students interested in earth science and the environment. The purpose of the Learning Center is to organize and deliver dynamic visualizations and information critical to understanding the complex processes of our environment. Learning Center development involves interface design and implementation, data visualizations, web programming, multimedia production, asset management and the development of collaboration tools for PRISM projects.

Learning Center Goals:

Finish initial on-line Leaning Center prototype

- Catalog and Presentation Tool
- Active pages and collaborative resources
- Real-time Interfaces

- Explorations and virtual environments
- Gallery of "best" content
- Learning Center utilities including links, news, calendars, and directories

Integrate PRISM Working groups and Learning Center

- Develop PRISM Steering Committee Active Page
- Provide easy pathway for incorporating Working-group content and documentation into Learning Center catalog
- Provide Learning Center support to the "Working-group" driven core courses (e.g.; Remote sensing classification, SWAMP, Drainage Basins)
- Refine collaboration tools

Learning Center Support for Puget Sound focus classes

Coordinate Learning Center activities with Geo-Spatial Initiative

Develop new content for Learning Center Explorations

- Real-time Weather
- Big Beef Creek - Salmon and Watersheds
- R/V *Thompson* - PRISM cruises and the oceanography of Puget Sound.

CEV will focus on content generation and collaboration interface development for the Learning Center. Content generation will involve the visualization of Puget Sound. CEV will explore new ways of looking at the physical, social, and biological Puget Sound area. To archive this we will visualize the model input/output from PRISM Science Working-groups.

Project prioritization

Given the limited resources, work will progress on visualization based on the priority ranking of data visualization projects submitted by Working Groups. Prioritization of data to be visualized will involve several factors:

- **Availability of data**. Non-proprietary data in the PRISM database, and data sets in standard PRISM format have high priority. New data and modeling of processes that have not been visualized before will also have high priority.
- **Target users**. Visualizations that will be used for educational purposes for UW graduate and undergraduate students have high priority.
- **Distribution of content**. Visualizations that can be widely distributed and used in the Learning Center have high priority.
- **Multiple uses**. Visualizations that have multiple uses or meet the needs of multiple groups inside and outside of PRISM have high priority.
- **Strategic Topics**. Visualizations that are strategic to Learning Center partner development have high priority.

The 2000-2001 plan includes delivering a well-designed Learning Center collaboration tool survey by the CEV team. The focus of the survey will be on meeting student-student and

instructor-student collaboration needs while continuing to assess potential opportunities with other user groups. Based on survey results, CEV will create new electronic tools and refine existing tools.

PRISM Web Site

The CEV working group will also work on the development and maintenance of the PRISM informational web site. The primary goal for this effort will be to improve linkages of the PRISM informational site with the individual Working Group web sites.

PRISM Resources for 2000-2001

Learning Center

PRISM funding for CEV salary will include: 25% for Mark Stoermer (Ocean & Fishery Sciences); 25% for Bruce Campbell (HITL); 25% for Hunter Headway (Ocean & Fishery Sciences); and 15% for Toby Latin (undergraduate student worker). Limited support for supplies, hardware and software. 20% for Susannah Iltis (Fisheries) for web site maintenance and development.

Adaptation of CEV visualizations for specific users and non-Learning Center delivery channels are possible but will require additional resources for media production. Media production includes creating graphic overlays on the visualizations, additional scientific illustrations, development of animation layers, and interface screen designs. Additional resources are also required for media editing and conversions.

Plans for Leveraging the UIF funds

CEV will seek to leverage PRISM UIF funds to further Learning Center Development. Specific plans include:

- Learning Center integration to the NSF-funded *Learning about Complex Environmental Processes in Immersive and Non-Immersive Virtual Environments* project.
- Partnership development with other environmental and educational technology projects within the University of Washington, including, digital library efforts, information science programs, on-line educational tool development and other environmental science education programs.
- Establish partners in non-traditional education arenas including, museums and aquariums.
- Explore resources available from foundations for public education
- Respond to appropriate RFPs concerning educational technology and environmental science

Role & Strategy

The educational role for PRISM is to make the interdisciplinary collaboration that goes into constructing the Virtual Puget Sound an integral part of teaching and educational outreach done by the faculty, students and staff that make up the PRISM Working Groups. By incorporating elements of PRISM into existing departmental courses and curricula, PRISM faculty will create a sustainable and coordinated program of activities that will have a wide impact on UW programs and student experiences. PRISM resources are targeted at the facilitation of classroom integration of the Virtual Puget Sound within the wide spectrum of relevant disciplines across the university campus. Externally-funded research and outreach efforts will provide exploration and evaluation of the effectiveness of PRISM's virtual environments for educating students and the public understand complex environmental processes.

PRISM's educational strategy is to prioritize the following related activities as the means of attaining the overall educational program goal of full integration with Working Group activities:

- **Curriculum Development and Integration:** PRISM supports technologies and staff to assist UW faculty in integrating PRISM's modeling and data resources as enrichments and improvements to their existing courses. Where possible, particularly as faculty develop new courses using PRISM as a foundation, PRISM resources should be used to promote and assist with the cross-listing of courses between relevant departments in order to promote interdisciplinary student and faculty participation.

- **Instructional Tools:** PRISM resources support faculty and instructors, in consultation with the Center for Environmental Visualization, to produce the educational materials necessary to meet the instructional requirements of curriculum development and integration, described above. This will be focused on support for development of a web-based virtual Learning Center to link PRISM's unique resources with instructional needs across campus and beyond the UW.

- **Experiential Learning:** PRISM-based research provides a rich array of projects for students from many disciplines as part of undergraduate and graduate research activities supervised by faculty and staff participating in PRISM Working Groups. Utilization of PRISM resources as part of service learning courses and studio courses are also a high priority. Faculty are encouraged to transfer their PRISM research into projects that can engage students to learn and discover more about the region in which we all live.

Progress in 1999-2000

In alignment with these strategies, 1999-2000 PRISM resources were focused on four project areas:

1. Enhancement of Existing Courses and Curricula

Courses with a significant interdisciplinary and integrated environmental content were assisted with faculty support, web site development, visualization and Learning Center resources. PRISM support was used to enhance the content and experiential component of pre-existing individual courses taught by faculty involved within PRISM Working Group research projects listed in Table 1.

Qtr	Course number(s)	Course Title	Instructor(s)	Enroll.	Description	PRISM Resource
Spring Qtr 2000	OCEAN 582A GEOL 490C/590C	River Basin Dynamics	Jeffrey Richey (Oceanography) David Montgomery (Geological Sciences)	12	This course explores how river basins are built and how they function in the transport of water, and particulate and dissolved chemical species from land to the oceans.	Salary support for Miles Logsdon, Jeff Richey, Ken Westrick. CEV support for visualization and Learning Center development.
Winter Qtr 2000	URBDP 467 OCEAN 506A	Land Cover Classification of Satellite Remote Sensing Data	Frank Westerlund (Urban Design and Planning) Miles Logsdon (Oceanography) Robin Weeks (Geological Sciences)	18	3 credits. Continuation of PRISM classification begun in Spring 99. An interdisciplinary approach to understanding the bases of classification of Satellite Remote Sensing data, applications of that data in research, and the skill set necessary for the construction of a classified Landcover dataset.	Salary support for Miles Logsdon and Robin Weeks, software and data for the project work.
Fall Qtr 1999	OCEAN 485	Oceanography of Puget Sound	Rick Keil (Oceanography)	25	1-5 credits. The primary objective of the course is to use Puget Sound as a tool for exploring the application of oceanography to relevant regional issues.	Web site development support by Bruce Campbell (HITL) and visualization assistance by CEV. Summer salary support for Rick Keil to develop PRISM content in course.
Summ er Qtr 1999	OCEAN 590B	Coastal/Estuary Geophysical Fluid Dynamics in Ocean and Laboratory	Peter Rhines (Oceanography) Stephen Monismith (Stanford) Craig Lee (APL)	15; 4 UW and 11 non-UW	The course emphasizes geophysical fluid dynamical processes of Puget Sound and the San Juan region. Course taught at Friday Harbor Laboratory, San Juan Island.	2 weeks salary support for lecturer Craig Lee; honoraria for Rocky Geyer (WHOI) for guest lectures

Table 1. Existing Courses that have utilized PRISM for Curriculum Development and Integration

2. Development of New VPS-and PRISM-Based Courses

In 1999-2000 three new highly-interdisciplinary and cross-listed seminar courses were developed. The 400-500 level seminars focused on the human aspects of Puget Sound environmental issues being addressed by PRISM and were cross-listed by all participating departments. A Freshman Seminar focused on the interdisciplinary studies and technologies within PRISM that will be utilized in the development of the Virtual Puget Sound.

Qtr	Course number(s)	Course Title	Instructor(s)	Enroll.	Description	PRISM Resource
Spring Qtr 2000	URBDP 498U GEOG 499B CFR 590U FM 490U FISH 497U POE 450U SMA 499U Public invited	Policy and Management of Human Influences on The Puget Sound	Robert Lee (Forest Resources)	100	1 or 2 credits. The PRISM sponsored lecture series is designed to address the policy and management processes affecting how human influences transform the Puget Sound Region.	1 quarter of TA support for Shannon Winger (Urban Design & Planning), summer salary support for Robert Lee.
Fall Qtr 1999	URBDP 498U GEOG 499B CFR 590U FM 490U FISH 497U POE 450U SMA 499U Public invited	Human Influences on the Puget Sound—Environmental Impacts	Robert Lee (Forest Resources)	95	1 or 2 credits. The purpose of this PRISM sponsored lecture series is to address the significant impacts caused by human induced changes to streams, lakes and marine processes in the Puget Sound Basin.	1 quarter of TA support for Shannon Winger in Urban Design & Planning. Support for video taping speakers.
Fall Qtr 1999	GEN ST 197 I	Freshman Seminar: Advanced Technologies in Ecosystem Modeling	Miles Logsdon (Oceanography)	17	Explore how ecologists use the latest in computer modeling, virtual reality, satellite imagery, global positioning receivers, and spatial analysis software to build an understanding of earth system processes.	Salary support for Miles Logsdon, speakers from PRISM projects.

Table 2. New Courses implemented to take advantage of PRISM resources and Virtual Puget Sound development

Spatial Analysis Initiative

In addition to the new courses listed in Table 2, a critical part of the PRISM education program was the development and successful implementation of a UIF2 Unit-specific proposal for inter-College support of a Coordinated Curriculum in GIS, Remote Sensing and Spatial Analysis for Earth Sciences and Natural Resource Planning. Miles Logsdon was supported in part by PRISM to develop this proposal and is now implementing this interdisciplinary and inter-college coordinated curriculum.

3. Research Assistantships, Internships, and Field experiences.

PRISM continued to recruit undergraduate and graduate students to contribute to its research agenda via research assistantships, internships and technical support for student activities related to their work with PRISM Working Groups and projects (Table 3).

PRISM-Supported Student	Faculty Supervisor	PRISM Project Affiliation
1. Amanda Babson, graduate Research Assistant in Oceanography	Mitsuhiro Kawase, Oceanography	Puget Sound Dynamics Working Group, Circulation Modeling Project
2. Amie Myers, graduate Research Assistant in Civil & Environmental Engineering	Richard Palmer, Civil & Environmental Engineering	Cascade Regional Yield Simulation and Analysis Model—CRYSTAL Project
3. Amir Sheikh, undergraduate Research Assistant in Geological Sciences	David Montgomery, Geological Sciences	Puget Sound River History Project

PRISM-Supported Student	Faculty Supervisor	PRISM Project Affiliation
4. Amy Groome, graduate Research Assistant in Civil & Environmental Engineering	Richard Palmer, Civil & Environmental Engineering	Cascade Regional Yield Simulation and Analysis Model—CRYSTAL Project
5. Cynthia Cooper, graduate Research Assistant in Quantitative Ecology and Resource Management	Charles Simenstad, Fisheries	NearPRISM Model Project
6. Erik Botsford, graduate Research Assistant Urban Design a& Planning	Marina Alberti, Urban Design & Planning	UrbanSim Model Project
7. Gudmundur Ulfarsson, graduate Research Assistant in Civil & Environmental Engineering	Paul Waddell, Evans School of Public Affairs	UrbanSim Model Project
8. Michael Noth, graduate Research Assistant in Computer Science & Engineering	Alan Borning, Computer Science & Engineering	UrbanSim Model Project
9. Joshua Latterell, graduate student in Fisheries	Robert Naiman, Fisheries	Coastal Cutthroat Trout Project
10. Jeramie Peterson, undergraduate Research Assistant in Fisheries	Thomas Quinn and Vincent Gallucci, Fisheries	UW Hatchery Salmon Life History Data Synthesis Project
11. Kevin McHugh, undergraduate Research Assistant in Atmospheric Sciences	Mitsuhiro Kawase, Oceanography	Puget Sound Dynamics Working Group, Circulation Modeling Project
12. Leo Lai, undergraduate Research Assistant in Computer Science & Engineering	Alan Borning, Computer Science & Engineering	UrbanSim Model Project
13. Leslie Pinnel, graduate Research Assistant in Computer Science & Engineering	Alan Borning, Computer Science & Engineering	UrbanSim Model Project
14. Matthew Dockrey, undergraduate Research Assistant in Computer Science & Engineering	Alan Borning, Computer Science & Engineering	UrbanSim Model Project
15. Michael Becke, undergraduate Research Assistant in Computer Science & Engineering	Alan Borning, Computer Science & Engineering	UrbanSim Model Project
16. Michele Koppes, undergraduate Research Assistant in Geological Sciences	David Montgomery, Geological Sciences	Puget Sound River History Project
17. Nathan Frier, undergraduate Research Assistant in Computer Science & Engineering	Alan Borning, Computer Science & Engineering	UrbanSim Model Project
18. Pascal Storck, graduate Research Assistant in Civil & Environmental Engineering	Dennis Lettenmaier, Civil & Environmental Engineering and Cliff Mass, Atmospheric Sciences	Atmospheric Modeling/Hydrology Working Group – AARM Project
19. Sara Marxen, graduate Research Assistant in Civil & Environmental Engineering	Richard Palmer, Civil & Environmental Engineering	Cascade Regional Yield Simulation and Analysis Model—CRYSTAL Project
20. Shannon Winger, graduate Teaching Assistant in Urban Design & Planning	Robert Lee, Forest Resources	PRISM Seminars, new courses for 1999-2000
21. Sherill Nelligan-Doran, graduate Research Assistant in Civil & Environmental Engineering	Richard Palmer, Civil & Environmental Engineering	Cascade Regional Yield Simulation and Analysis Model—CRYSTAL Project
22. Toby Latin, undergraduate Research Assistant in pre-engineering	Mark Stoermer, Ocean & Fishery Sciences, Center for Environmental Visualization	Learning Center Project

23. Table 3. Students Supported by PRISM, 1999-2000

PRISM Cruises in 1999-2000

Since 1997, PRISM has partnered with the School of Oceanography to sponsor cruises on the R/V *Thomas G. Thompson* with a joint purpose of gathering oceanographic data from Puget Sound and educating/involving students, both graduate and undergraduate, in the collection and analyses of the data. In 1999-2000, two PRISM cruises included over 40 undergraduates graduate students in field work on Puget Sound. Students, together with the PRISM scientists on the vessel, used this field work to help build the PRISM data base and models (Table 4). The School of Oceanography funds the ship time and PRISM provides the staffing and support for chemical analysis of water sampled on the cruise.

Dates	From	To	Participants	Chief Scientist
August 15 - 19, 1999	Eureka, CA	Seattle	17 students	Jan Newton, WA Dept. of Ecology & UW Oceanography
December 19 - 22, 1999	Seattle	Seattle	14 students	Mark Warner, Oceanography
June 12 - 15, 2000	Seattle	Seattle	10 students	Mitsuhiro Kawase, Oceanography

Table 4. PRISM Cruises supported in 1999-2000

During the cruises, PRISM participants occupy 40 station from South Puget Sound to the Strait of Juan de Fuca, including Hood Canal and Whidbey Basin. Students are trained to "run" the station, with each person having a specific role (e.g., sampler, "Water cop", CTD/Computer technician, analyst). PRISM scientists could not accomplish the volume of work without the students, so students know that they are instrumental in collecting this state-of-the-art data. Some students have come out for several cruises, each time selecting a new role. Students not only do research, but can find out first-hand which type of oceanographic research interests them as a future career direction.

On the cruises, the data types that are collected include: CTD, nutrients, oxygen, chlorophyll/phaeopigment, CFS, productivity, plankton, light. A few other measurements like DIC and stable C isotopes have been done occasionally as research needs dictate. On the PRISM cruises students receive direct training in these highly-marketable laboratory skills. But they know that they are also doing work that will be useful to others in the research community and that the cruise is not just a class exercise. The data are used for analysis of water quality, ecosystem integrity, and as input data for PRISM models on the physical, chemical and biological aspects of Puget Sound. The data are sorely needed, as comprehensive environmental snapshots such as these do not exist for Puget Sound.

Students are recruited for PRISM cruises from oceanography classes and general announcements to the UW. State and King County agencies have also participated in these cruises to obtain data on water quality for their agencies. Students get to meet and work side by side with these agency scientists and many UW students have obtained job offers or internships as a result.

Undergraduate Research Symposium

On May 12, 2000, PRISM participated in the third annual UW Undergraduate Research Symposium. PRISM was the topic of a panel discussion moderated by Linda Maxson (OMERP) that included participants Jeffrey Richey (Oceanography), Jonathan Frodge (King County), Barbara Cairns (Long Live the Kings) and undergraduate researcher Angela Norbeck

(Oceanography). The topic of the discussion was "The Role of Research in Society: The Puget Sound Regional Synthesis Model (PRISM)." The panel was video taped and broadcast on UWTV in the Spring and Summer quarters.

4. Educational Technology Research

PRISM Working Groups continued to collaborate with faculty within the College of Education to support the NSF-funded research project "Learning about Complex Environmental Processes in Immersive and Non-Immersive Virtual Environments" to develop innovative ways to visualize, deliver and use models and data for educational purposes within the UW and across the K-20 spectrum. In 1999-2000, PRISM databases and models provided the context for students learning about the Puget Sound environment. The virtual environment being developed is based on data produced from the model of water circulation in Puget Sound and from data gathered by the R/V *Thomas G. Thompson*. Working with the Center for Environmental Visualization and the Human Interface Technology Laboratory, two- and three-dimensional visualizations of data were constructed.

The goal is to build interfaces that allow students to interact with the visualizations, to move through the environments, to design tasks that will lead them to build knowledge of what is happening in the environment, and to assess their understanding in a variety of ways. The interface will allow students considerable freedom to alter environmental parameters and observe the change in scenario outcomes.

Plans and Resources for 2000-2001

Curriculum Development and Integration

PRISM's focus for 2000-20001 educational program resources will be to facilitate the collaboration of the Working Groups with the new course development that is part of the UIF2-funded Unit-specific Program for *Coordinated Curriculum in GIS, Remote Sensing and Spatial Analysis for Earth Sciences and Natural Resource Planning*. This UIF2 project, developed in consultation with PRISM, initially establishes a coordinated teaching program for undergraduate and graduate education in spatial analysis for earth sciences and natural resource planning in the College of Ocean and Fishery Sciences and the College of Forest Resources. PRISM will continue to provide salary, data and modeling support to the courses being developed by Miles Logsdon for this program.

PRISM is supporting this program because it shares the common goals to open lines of communication and coordination of interdisciplinary environmental studies to meet student and faculty needs. PRISM Working Groups will provide a foundation of data, modeling and regional context for the new courses in Spatial Analysis and Ecosystem Modeling that are being developed.

Instructional Tools—The Learning Center

PRISM's 2000-2001 resources for instructional tool develop will continue to go toward the development of the Learning Center. The Learning Center is a joint development of the Center for Environmental Visualization, the Human Interface and Technology Laboratory and PRISM. It is a collaborative resource for faculty, students, staff, K-20, and the public interested in earth sciences and the environment. The goal of the Learning Center is to organize and deliver dynamic visualizations and information critical to understanding the complex processes of our environment. In addition, the PRISM web site will be adapted to feature the Active Pages of the Learning Center technology and provide a means for PRISM to share more dynamic data, modeling and visualizations with its users. For more information and details, see the project description in Part 2 of this report.

Experiential Learning

Undergraduate and graduate student participation in research, education and outreach via the Working Groups is integral to all of PRISM's 2000-2001 program plans. Direct student salary support is being planned for:

PRISM-Supported Student	Faculty Supervisor	PRISM Project Affiliation
Amie Myers, graduate Research Assistant in Civil & Environmental Engineering	Richard Palmer, Civil & Environmental Engineering	Cascade Regional Yield Simulation and Analysis Model—CRYSTAL Project
TBD, graduate Research Assistant	Charles Simenstad, Fisheries	NearPRISM Model Project
Michael Noth, graduate Research Assistant in Computer Science & Engineering	Alan Borning, Computer Science & Engineering	UrbanSim Model Project
Sara Marxen, graduate Research Assistant in Civil & Environmental Engineering	Richard Palmer, Civil & Environmental Engineering	Cascade Regional Yield Simulation and Analysis Model—CRYSTAL Project
Toby Latin, undergraduate Research Assistant in pre-Computer Science & Engineering	Mark Stoermer, Ocean & Fishery Sciences, Center for Environmental Visualization	Learning Center Project

Table 5. Students Supported by PRISM, 2000 -2001

Puget Sound Research Conference

PRISM support will continue to fund student research projects on PRISM cruises and to support the presentation of student research results at symposia. This will help our faculty and students improve our regional understanding of Puget Sound and to communicate their results with interested partners. In 2000-2001 PRISM Working Group members, particularly students, will be encouraged to submit papers for the 2001 Puget Sound Research Conference on February 12-14, 2001 in Bellevue. This biennial conference is focused on applying research findings to environmental management and decision-making in our region.

PRISM Cruises

PRISM will support the analysis of samples by students on two cruises in 2000-2001. Ship time is funded by the School of Oceanography in partnership with PRISM. Undergraduate and graduate students from any environmental science field are invited to participate to find out more about Puget Sound and how oceanographic field work is done. Observers and participants from a variety of state and local agencies are also invited to participate and take part in the cruises.

Dates	From	To	Participants	Chief Scientist
December 18 - 23, 2000	Seattle	Seattle	14 students	Mark Warner, Oceanography

Table 6. PRISM Cruises planned for 2000 -2001

Educational Technology Research

PRISM collaboration with the NSF-funded research project "Learning about Complex Environmental Processes in Immersive and Non-Immersive Virtual Environments" will continue in 1999-2000. The second scenario for interface development will be focused on the Big Beef Creek watershed, and the UW's Big Beef Creek Field Station will provide the support for student field work. This scenario requires students to develop an understanding of the complex factors that contribute to flooding. The environment is constructed from data provided by the DHSVM hydrology model for the Big Beef Creek watershed in Kitsap County.

The Learning Center Project being done by the Center for Environmental Visualization, the Physical Template Working Group and the GIS/Spatial Analysis UIF2 Program, both being led by Miles Logsdon and supported by PRISM, will collaborate with this research program to assist in the development of two- and three-dimensional visualizations of data from Big Beef Creek. The goal is to build interfaces that allow students to interact with the environmental visualizations, to design tasks that will lead them to build on their knowledge of what is happening in the environment, and to assess their understanding in a variety of ways.