
The Washington Water RESOURCE

The quarterly report of the Center for Urban Water Resources Management

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CONTENTS

- 1**
Message from the Director
- 2**
New update of the
Urban Issues Library
- 2**
Evaluation of Factors Affecting
Infiltration Pond Performance
- 6**
Brief summaries of some current
and upcoming projects
- 10**
Department of Civil and
Environmental Engineering
professional development
opportunities
- 11**
Publication update of current
projects at the Center

Message from the Director

This issue of the Newsletter presents an overview of some of the current projects we are actively engaged in this year, together with the summary report of a study on the use and design of infiltration ponds. As stormwater management continues to expand beyond its traditional roots as a simple “flood-control” issue, the range of mitigation approaches has also broadened beyond simple hold-and-release detention ponds or bypass pipelines. These broadened approaches, particularly those involving infiltration and overall site design, also demonstrate the interconnectedness of “water resource management”—surface water may become groundwater, stormwater discharges may ultimately find their way (or be actively introduced) into drinking water aquifers, and the next generation of solutions to water management issues may be developed by landscape architects and urban planners as well as by civil engineers.

The merger of the Center for Urban Water Resources Management and the Center for Streamside Studies has now received all but the final set of necessary approvals by the University. The new name of our combined center will be the *Center for Water and Watershed Studies*, which you will continue to find on the web through either of its predecessors’ sites and from which you will continue to receive newsletter issues. We anticipate the formal combination of these two water-resource centers will occur September 1, 2002. As befits such an event we are planning a celebration, to which you (and your colleagues) are hereby invited: **Friday, September 6th, 2002, 3:30-6:00 at the Waterfront Activities Center** (behind Husky Stadium). Faculty, students, and advisory boards are all very excited about continuing with the growing collaboration of different disciplines across campus; please come and meet many of those who are involved in that work on September 6th. Beyond that time, I hope that this closer collaboration of efforts will also improve our service to and support across the region.

Derek Booth ♦

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New update of the Urban Issues Library

The Urban Issues Document Database, available on-line through the Center's web site (see the PUBLICATIONS pages) and the Salmon Information Center, was updated in June 2002. About 130 articles were added, bringing the total number of database documents to over 600. Although most of the articles relate to anadromous salmon recovery in the Pacific Northwest, several articles discuss relationships between anthropogenic watershed and riparian changes and the resulting stream ecological and physical impacts. Most of the additions (59%) were journal articles published since 1999. The pie chart below illustrates the percentage of new entries in the following 7 categories: (1) pre-1999 (all sources and subjects); (2) theses and dissertations since 1999; (3) articles particular to WRIAs 8 and 9 (post-1999); (4) urbanization and land-use impacts in the PNW, (5) other PNW-related articles, (6) general articles on urbanization and land-use impacts, and (7) other, general stream-related articles. ♦

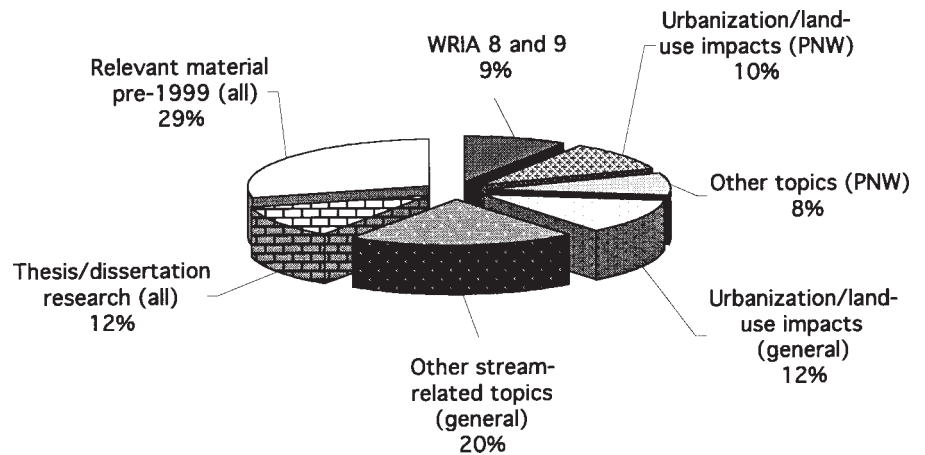


Figure 1
Main Categories for New Entries in the June 2002 Database Update

Evaluation of Factors Affecting Infiltration Pond Performance

By Stephanie Stolar, Graduate Research Assistant, Department of Civil and Environmental Engineering

INTRODUCTION

The increasing urbanization of watersheds in Western Washington over the last decade has forced stormwater management guidelines to respond to growing concerns about the degradation of streams and wetland resources. In the past, stormwater management was viewed as a quantity-control problem where stormwater detention ponds, dry wells, and swales were used to reduce peak flows that contributed to flooding and erosion in stream channels. Since the current shift is toward stormwater management practices that also address water quality control of runoff, groundwater infiltration ponds have become an increasingly popular alternative in controlling urban runoff (Figure 1). These ponds direct all of the stormwater they receive into the ground instead of passing it on directly to surface water bodies. Important benefits of groundwater infiltration ponds include reducing surface-runoff volume, providing groundwater recharge, reducing thermal impacts on fisheries, and augmenting low-flow stream conditions. Since the implementation of infiltration ponds used to store and infiltrate runoff is relatively new, the design of these systems has been changing rapidly as new understanding about them is collected.

Continued on page 3

EVALUATION OF FACTORS AFFECTING INFILTRATION POND PERFORMANCE
(from page 2)

The objectives of this study were:

1. To describe the analytical techniques and numerical models that are currently available to design groundwater infiltration ponds.
2. To identify the important input parameters in the design of infiltration ponds.
3. To use groundwater flow models to determine the sensitivity in the overall function of the infiltration pond to different input parameters.
4. To develop recommendations, based on modeling results, that can be used in site characterization and future pond design.

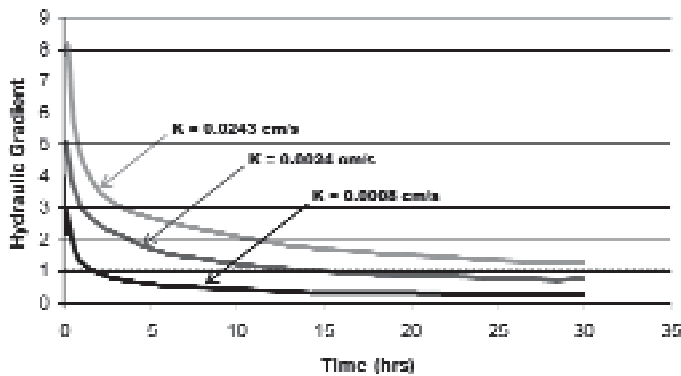


Figure 1.

Schematic of an infiltration pond (from Washington State Department of Transportation)

Recent work by Butchart (2001; also see the Spring 2001 issue of the Newsletter) supplemented existing manual guidelines on infiltration ponds by examining small-scale issues related to estimates of infiltration rate. This report expands on her work by studying the large-scale infiltration pond system from a modeling perspective. Both projects have been partially funded by the Washington Department of Transportation (WSDOT).

EVALUATION OF INFILTRATION POND PERFORMANCE

Under the assumption of steady-state saturated flow, a base model of a “typical” pond was developed in MODFLOW to evaluate different design alternatives. This model is loosely based on the dimensions of and observed subsurface geology beneath an infiltration pond in Lacey, Thurston County, WA. The three-dimensional grid representing the pond covers an area of 1554 meters by 1524 meters. The pond is located in the center of the model domain, has an area of 37 by 73 meters, and is 1.5 meters deep. The elevation at the bottom of the model was set at 0 meters and the top of the model was set at 44.2 meters.

The model is divided into five horizontal layers that represent regions with distinct hydrogeologic properties (Table 1):

Layer	Description	Hydraulic Conductivity (cm/s)	Porosity
1	Region around and immediately below the infiltration pond	0.0353	0.21
2	Confining unit between the upper unconfined aquifer (layer 1) and the lower confined aquifer (layer 4)	0.00353	0.21
3	The space of the pond itself, (no aquifer matrix)	35.3	0.9999
4	Confined aquifer below layer 2	0.0353	0.21
5	1-m-thick layer directly beneath the footprint of the infiltration pond, simulating special pond-construction treatments	0.0353	0.21

Table 1:

Descriptions and hydraulic parameters for each layer

To test the sensitivity of the pond to different conditions, the hydraulic parameters in these layers were varied. For example, when a gravel bed beneath the pond was simulated, the hydraulic conductivity of layer 5 was increased to a value consistent with gravel.

Factors in Pond Performance

Water Table Elevation and Lateral Flow

A series of simulations was performed to quantify the change in the infiltration rate that occurs from water-table fluctuation below the pond and to determine the amount of lateral flow out of the pond. Substantial changes in overall infiltration rate were observed from variation in the water tables, emphasizing the importance of understanding regional water-table variations at a proposed infiltration pond site. If, for example, an infiltration test is performed in the summer when regional water table elevations are low, the measured infiltration rate could be twice the rate that would be observed in the winter when the water table levels rise.

Changes in water-table elevation have little effect on the percent of the flow that occurs through the sides of the infiltration pond. There is a slight increase in the lateral flow as the water table approaches the pond bottom, but about one-third of the flow from the infiltration pond leaves through the sides under all the modeled conditions.

Pond Geometry

Table 2 shows infiltration rate variations resulting from changes in the pond geometry. For all the ponds the area of the footprint, the depth of the pond and the water level in the pond are the same. The infiltration rate increases as the pond becomes more elongate, attributed to the increase in the lateral flow that occurs as the pond perimeter increases.

Continued on page 4

EVALUATION OF FACTORS AFFECTING INFILTRATION POND PERFORMANCE

(from page 3)

Pond perimeter (m)	Pond dimensions (m x m)	Water table elevation (m)	Infiltration rate (cm/hr)	% outflow through sides
207	51.7 x 51.7	36.6	17.4	30.7
219.5	36.6 x 73.2	36.6	17.7	31.4
329.3	146.3 x 18.3	36.6	20.2	35.5

Table 2:

Infiltration rates for different pond perimeters

Water Level in the Pond

The sensitivity to the water level in the pond was investigated by changing the constant head boundary in Layer 3 (the inside of the pond) to represent progressively lower levels of water in the pond. The results of Table 3 suggest that the decrease in the total infiltration rate that accompanies lowering the water level in a pond is largely a result of a decrease in the amount of lateral flow. For all the pond depths, the amount of water that exits the bottom of the pond is similar.

Depth of water in pond (ft)	Percent change in infiltration rate		
	Total	Bottom	Sides
1.5	--	--	--
1.2	-8	-0.8	-22
0.9	-11	-0.8	-30
0.6	-17	-1.8	-43

Table 3:

Changes in infiltration rates caused by varying water depths in pond

Gravel Base

A series of simulations were run to quantify changes in infiltration rate due to replacement of the natural soil beneath a pond with the addition of 0.9 meters of highly permeable material beneath the footprint of the infiltration pond. For all the water-table elevations considered, the increase in the total infiltration rate ranges from 0.8% to 1.8%. While there is substantial increase in the amount of flow out the bottom of the pond, this is counteracted by the decrease in the amount of lateral flow, which in combination results in an insignificant increase in total infiltration rate.

Evaluations of Hydraulic Gradients Beneath Infiltration Ponds

The design of an infiltration pond requires an accurate description of the infiltration rate. Currently, the state stormwater manual uses the simplest design method to compute the hydraulic gradient by assuming a constant vertical hydraulic gradient of 1.0 for infiltration ponds. Others, such as

Ferguson (1994) and Stahre and Urbonas (1990), also recommend using a constant vertical hydraulic gradient of 1.0, and they consider this value to be a conservative estimate. This assumption makes the infiltration rate equal to the hydraulic conductivity of the subsurface material. Unfortunately, this simplified method, which is common practice, does not account for the possibility of hydraulic gradients being less than one.

If a hydraulic gradient of 1.0 is used in the design process but the actual value is lower, the pond size will be too small. Prolonged periods with the hydraulic gradient less than one will cause flooding from the infiltration pond, since the pond will have been designed to store a lesser amount of water. Conversely, there is a cost associated with underestimating the hydraulic gradient, because land will be used for an infiltration pond that could have been used for other purposes. Because of the importance of hydraulic gradients in pond design, the next two sections examine the behavior of hydraulic gradients.

Gradient Changes in Transient Unsaturated Flow Model

A transient unsaturated flow model was used to monitor the time evolution of the hydraulic gradient beneath an infiltration pond for different soil types during a 30-hour recharge period. Darcy's law was used to solve for the hydraulic gradient at each time step. Since the flow leaving the pond (Q) at each time step is known, the hydraulic gradient can be solved for:

$$i = \frac{Q}{AK}, \quad (1)$$

where i is the hydraulic gradient, A is the area of the wetted perimeter, and K is the hydraulic conductivity of the material beneath the pond. This hydraulic gradient will control how much water can pass through the pond. A duration of 30 hours was chosen for these simulations, since state regulations require that infiltration ponds drain within 24 hours.

Initially, hydraulic gradients are high because the length of the wetting front is low. As the wetting front length increases, the hydraulic gradient quickly decreases. If the wetting front never reached the water table the hydraulic gradient would eventually approach 1.0. However, when the wetting front does reach the water table, the gradient is forced below 1.0.

For ponds in a medium sandy soil (K=0.875 m/hr), the hydraulic gradient decreases to below 1.0 after only 2 hours of infiltration. For a fine sand with a hydraulic conductivity of 0.0875 m/hr, the hydraulic gradient decreases to below one after 17 hours; for a sandy loam with a hydraulic conductivity of 0.0292 m/hr, the hydraulic gradient remains greater than one throughout the 30-hour simulation period. These results demonstrate that, in highly permeable soils, assuming a hydraulic gradient of 1.0 is not conservative. Conversely, in low-permeable soils, assuming a hydraulic gradient of 1.0 may be overly conservative.

RECOMMENDATIONS

Continued on page 5

EVALUATION OF FACTORS AFFECTING INFILTRATION POND PERFORMANCE

(from page 4)

Design Implications

Often, it is not practical to perform a site-specific modeling study to discover how the infiltration rate will vary according to certain parameters. The recommendations made in this section acknowledge this and instead present suggestions based on the experiences gained by the modeling.

Soil Type	Depth to groundwater (m)	Recommended hydraulic gradient for design
Clean sandy gravel and gravelly sands	> 6	< 0.3
	6-Mar	< 0.2
	0-3	< 0.1
Sand	> 6	0.5 - 0.8
	6-Mar	0.3 - 0.5
	0-3	0.1 - 0.4
Loamy Sand	all depths	1
Sandy Loam	all depths	1
Loam	all depths	1

Table 4:

Hydraulic gradient estimates for different soil types and groundwater depths

Water Table Elevation and Hydraulic Gradient Estimates

An appropriate hydraulic gradient estimate is necessary to ensure accurate infiltration pond design. Table 4 gives suggested hydraulic gradients for different soil types and depths to the water table. For loam, sandy loam, and loamy sand soils the suggested gradient estimate is 1.0 for all groundwater depths, because the hydraulic gradients of these systems will not decrease below 1.0 within the 24-hour time required for the pond to empty. Using a value of 1.0 in these situations is conservative since the gradient is initially much higher than 1.0. In contrast, the hydraulic gradient will be less than 0.3 at steady-state for a medium sandy soil. For sandy soils and gravelly sands, the hydraulic gradient suggestions below reflect these results.

Monitoring of yearly fluctuations in water table elevations needs to be done beneath every infiltration pond. Modeling results suggest that an increase in the water-table level of only 1.5 meters can decrease the net infiltration rate by 17%. At a minimum, a monthly sampling of groundwater levels should be required. The yearly minimum level should be used with Table 4 to select the proper gradient estimate. If a perched aquifer exists, the depth to this aquifer should be used instead.

Soil Type Infiltration Rates

The results of the modeling simulations emphasize the fact that infiltration ponds are most efficient at infiltrating runoff when they overlie permeable soils. The modeling of the hydraulic gradients, however, indicates that the soil permeability cannot always be considered to be equal to the infiltration rate. Table 4 can be used to obtain a conservative estimate of hydraulic gradient to ensure that flooding will not occur. These values should be multiplied by the hydraulic conductivity estimate to determine the infiltration rate for the site. Also, if there is a perched water table beneath an infiltration pond, it is recommended that the depth to this perched layer be used rather than the depth to the regional groundwater level.

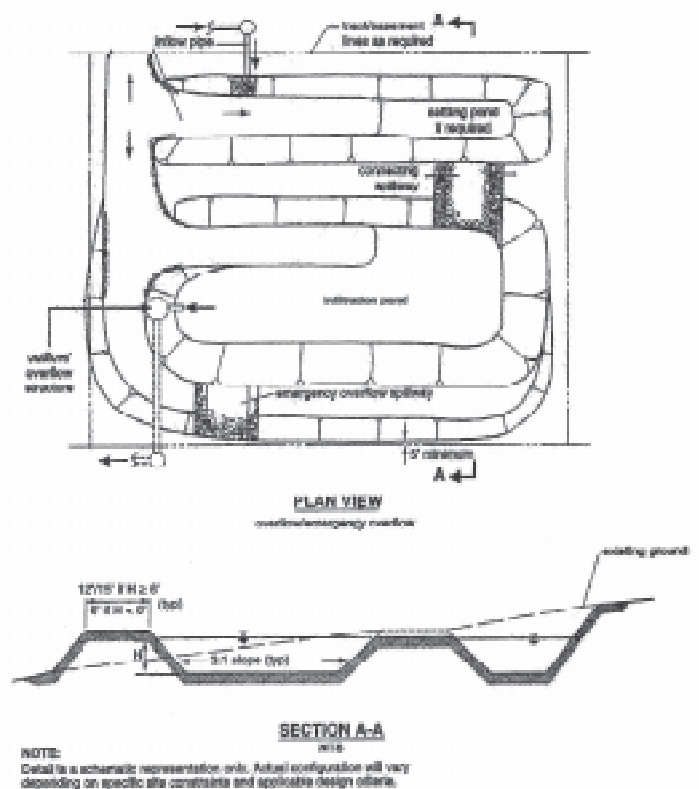


Figure 2.

Changes in hydraulic gradient over time for three different substrate permeabilities. The more permeable the underlying sediment, the more rapidly the infiltrating water "mounds up," reducing the effective hydraulic gradient below a value of 1.

Continued on page 6

EVALUATION OF FACTORS AFFECTING INFILTRATION POND PERFORMANCE

(from page 5)

Pilot Infiltration Test Recommendations

During a pilot infiltration test (PIT), the depth to the groundwater should be determined. This value, along with the soil type around the pond, should be used with Table 4 to determine what the hydraulic gradient estimate might have been during the test. Then before the pond is constructed, yearly water-table fluctuations should be compiled for the site to see if the hydraulic gradient estimate from the PIT is applicable. If it is found that the water table is generally much higher than when the PIT was done, a correction of the infiltration rate should be made. If the soil beneath the pond is not very permeable, then no correction is needed.

Presence of a Confining Unit

The variability in infiltration rates caused by confining units significantly below the ground surface should be included in a safety factor. Currently, the WADOE regulation only specifies that units to a depth of 2.5 times the depth of the pond are evaluated to determine if they will act as confining units. However, modeling confirms that even confining units at depths greater than 10 meters can affect the infiltration rate. If geologic maps or subsurface exploration at a proposed site indicate that there is a substantial constricting unit beneath the site, such as a glacial till layer, then the correction factor may need to be increased.

Pond Geometry

Since the changes in infiltration rates are small for variations in pond perimeter, pond geometry is not an important design criterion. However, constructing an elongated pond, rather than a square pond, will allow for a slightly higher performing pond per area of land.

Lateral Flow

The results from this study found there is a significant amount of lateral flow out of infiltration ponds full of water. Since current design regulations do not include any provision for the additional infiltration that occurs through the sides of a pond, these results suggest that ponds could be designed smaller than the current design method recommends. However, the simulations that examined the effect of water level in the pond showed that decreases in infiltration rates as the water level was lowered came almost entirely from the reduction in the lateral flow. If the pond drains promptly after receiving runoff then lateral flow will not be significant. To further complicate the situation, Butchart (2001) presented evidence that under certain conditions, water may even flow back into the pond through the sides because the head within the pond is lower than the head outside the pond. Due to the large amount of uncertainty concerning the issue of lateral flow from an infiltration pond, additional research in this area is needed before incorporation into design standards is appropriate.

CONCLUSIONS

The following conclusions can be made based on the finding of this study:

- **Hydraulic gradients beneath infiltration ponds situated in permeable soils are significantly less than 1.0.**

At steady state, the hydraulic gradient beneath an infiltration pond is less than 1.0 for medium sandy soils or those more permeable. Additionally, transient simulations of infiltration ponds overlying permeable soils suggested that steady state was reached within hours, emphasizing the importance of the steady-state results.

- **Monitoring of yearly water table fluctuations beneath infiltration ponds is necessary to insure proper design.**

Relatively small changes in the water table elevation resulted in significant variations in the infiltration rate. Additionally, more permeable soils were most sensitive to changes in the water table.

- **Lateral flow from infiltration ponds is high when the pond is filled.**

The flow of water out the sides of the pond can comprise nearly one-third of the total flow from a full infiltration pond. The contribution of lateral flow is directly proportional to the water level in the pond. Lateral flow will be the greatest when the pond is full and needs to drain quickly; for typical filling/emptying cycles, it is estimated to be about 10% of the total infiltration volume. Future work should evaluate the contribution of lateral flow under more realistic pond filling and draining sequences.

- **The geometry of an infiltration pond is not an important design consideration.**

The infiltration rate is linearly proportional to the perimeter of an infiltration pond. However, modeling results suggest that the infiltration rate will increase only modestly for large increase in the pond perimeter (for a given total pond volume).

- **Adding a layer of gravel or a gravel column below a pond does not significantly increase the steady state infiltration rates.**

These two design modifications never increased the infiltration rate by more than 2%.

- **Steady-state saturated flow simulations will give useful information for infiltration ponds when the soils below the pond are permeable.**

Comparisons between steady-state saturated flow simulations and transient unsaturated flow simulations indicate that steady state will be reached quickly in permeable soils. The errors introduced in modeling saturated flow rather than unsaturated flow are low relative to errors introduced by the characterization and generalization of aquifer properties and the enforcement of boundary conditions. More complex modeling tools may give more accurate results but may not be worth the additional cost.

Continued on page 7

EVALUATION OF FACTORS AFFECTING INFILTRATION POND PERFORMANCE

(from page 6)

These conclusions are valid, however, only under a particular set of conditions:

- Modeling results neglect the impact of clogging on the surface of the pond, so it has been assumed that the site is well maintained.
- The constant-head boundary imposed within the infiltration pond assumes the pond is full of water. In reality, the pond continually drains and fills as series of storms affect the area.
- The initial conditions for the transient model specified a horizontal water table with dry soils above. Since ponds are constantly in a state of flux, the soils above the pond will likely have varying degrees of saturation.
- The ponds have been modeled using a simplified hydrogeologic setting. Variations in the extent and properties of the subsurface strata are inevitable, especially in the fluvial-glacial sediments common to western Washington.

In spite of these limitations, results have shown that current design practice is *not* conservative. This could explain the common cases of observed failure of infiltration ponds in the region.

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- Ferguson, B.K., Stormwater Infiltration, CRC Press, Inc., 1994.
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Brief summaries of some current and upcoming projects

Evaluating the quality and quantity of stormwater from new management techniques

Seattle Housing Authority's plan to rebuild the High Point housing in West Seattle has opened an opportunity to install up-to-date stormwater management techniques in a large area contributing drainage to Longfellow Creek, a stream with existing and potential salmon habitat. The Center for Urban Water Resources Management (the Center) will assess the performance of the selected techniques through flow and water quality monitoring of High Point's stormwater runoff. The Center's work will include developing the monitoring plan, helping in equipment installation, operating monitoring stations, collecting flow data and water samples, performing certain analyses, delivering samples to the city's contract labora-

tory for other analyses, archiving and analyzing all data, and interpreting and reporting results. Phase 1 will emphasize collecting baseline data (representing the existing condition) and the first set of post-construction data at the point where collected stormwater runoff from the entire neighborhood discharges to the creek. Future phases, under anticipated follow-up contracts, will continue monitoring at this point and will add monitoring of discharges from selected stormwater management facilities installed to treat runoff from drainage subbasins. Beyond this contract, the city will contribute equipment, technician assistance, and the cost of laboratory analyses.

Independent Science Review Team for "normative flow"

Flow regime is a key factor in any jurisdiction's ability to play a constructive role in local and regional efforts to achieve conservation goals for aquatic ecosystems because the success of habitat protection or restoration actions often depends on a supply of the appropriate amount of water at the appropriate time. Yet human activities have altered the flow regime in many rivers and streams in ways that may jeopardize the efficacy of those habitat actions. "Normative Flow" is an advantageous concept for considering how flow regimes could be influenced by human actions in beneficial ways. This concept stresses the importance of pattern and temporal variation in flow attributes—not only magnitude but also frequency, duration, timing, spatial distribution and rates of change—in creating and sustaining the complex instream and floodplain conditions to which naturally spawning salmon have successfully adapted over centuries of evolution. Its emphasis on multiple aspects of the flow regime that create and sustain suitable habitat conditions, in contrast to the emphasis of simplistic minimum (or maximum) flow analysis concepts, is what distinguishes the normative concept and establishes its promise and appropriateness for application in an ecosystem-based conservation and recovery strategy.

CUWRM has been asked to convene and facilitate a Science Review Team composed of national experts on the normative approach to hydrologic management. Its members are James Karr, faculty member in Fisheries and Zoology at the University of Washington; Bob Milhous, hydrologist for U.S. Geological Survey's Stream and Riparian Ecology Section; LeRoy Poff, faculty in Biology at Colorado State University; and Chris Frissell, staff scientist at the Pacific Rivers Council and faculty in Fisheries at the University of Montana. The team will assist in the following tasks:

1. Clarify the conceptual framework and assumptions that underlie the ecological flow model of river conservation;
2. Assist in the development of a statistical method to analyze flow regimes;
3. Assist in the development of the ecological evaluation model required to link flow regime with ecological effects;
4. Review the application of these tools to specific streams and rivers;

Continued on page 8

BRIEF SUMMARIES OF SOME CURRENT AND UPCOMING PROJECTS
(from page 7)

5. Assist in the development of ecological goals and objectives for conservation on these rivers; and
6. Assist in the development of both general and river-specific normative guidelines.

“Alternative futures” for watershed land use in Chico Creek

The “Alternative Futures” approach to watershed management and planning offers the opportunity to integrate scientific information from a wide variety of resource management and land use planning objectives, creating a single framework to aid communities in the comprehensive assessment of future development trajectories. The approach has been used in Oregon to assess current watershed conditions and to produce a series of maps that compare the impacts of current practices and trends in land development. Chico Creek on the Kitsap Peninsula has been selected as a pilot project for the Alternative Futures approach in the Puget Sound region by the Puget Sound Water Quality Action Team and EPA Region X, and they have asked the Center to assist by providing technical support in several areas:

- Recommended methodologies for evaluating the existing and future health of aquatic ecosystems;
- Information for conducting hydrologic, geomorphic, water-chemistry, and biological analyses of the consequences of land-use changes on aquatic systems;
- Techniques and procedures for linking land-use scenarios with quantitative predictions of hydrology, stream-channel geomorphology, water chemistry, and in-stream biological conditions, following the general framework and approach of recent watershed plans; and
- Methods for delivering the results of predictive models of the influence of land-use changes on streams to a broader, nontechnical audience.

For the Chico Creek watershed, we will assemble the technical output (hydrologic monitoring and modeling, channel information, and relevant GIS datalayers) from others into an integrative framework that characterizes local stream and overall watershed health. The scope and structure of these metrics, GIS analyses, and models will be developed in collaboration with appropriate parties with the goal of helping Kitsap County make informed decisions related to watershed health and resource management. All presently identified ecological measures are influenced to some degree by land use practices and management. We anticipate emphasizing riparian zones, given the presently low level of knowledge and the likely high level of impacts on aquatic resources. Our goal is to develop specific links between riparian conditions and instream processes and conditions, drawing from various physical, chemical, and biological measures to fill in critical gaps in our understanding of

watershed health. Following initial development of the tools, we will transition from developing a site-specific study to a more general approach.

Application of a Sediment Budget to Assist Urban Stream Rehabilitation

Chase Barton, Graduate Research Assistant

Changes in land use and hydrology resulting from urbanization alter the processes of sediment production, delivery and transport within a watershed. As part of a multi-phase project to improve instream habitat, a sediment budget is in progress for the Pipers Creek watershed, a 7.5-km² urban watershed largely contained by Carkeek Park in the northwest part of Seattle, Washington. Pipers Creek supports multiple salmonid species, although many decades of watershed urbanization have greatly reduced historic returns. Of the many urban-induced impacts that have been or might be evaluated here, this project is focusing on the variable effects of ongoing channel enlargement and stream bank stabilization, which in turn may threaten the long-term availability of adequate spawning gravel in the stream. Sediment-delivery rates for park and urban components of the watershed, determined through field observations and measurements, include contributions from channel enlargement, landslides, gully erosion, soil creep, and urban runoff. Channel surveys provide estimates of sediment storage in addition to substrate composition and character. Together, these data display current patterns in the quantity, quality, and distribution of sediment within the creek system. Although preliminary, results are suggesting likely imbalances in delivery and transport of both the coarse and fine sediment fractions of the channel network.

Measurement and Identification of Controls on Stream Temperature

Keith Cherkauer, Research Scientist

Stream temperature is a significant water quality concern in the Pacific Northwest, where warm water can be lethal for indigenous fish species and coldwater refugia are essential for the survival of threatened and endangered salmon. This necessitates regional-scale assessments of water temperature for compliance monitoring. Two methods have been historically used to observe stream temperatures in the Puget Sound region. The first makes use of a large number of volunteers, who take many measurements at predetermined locations in a brief period of time when high summertime temperatures are anticipated (the Center’s regional Stream Temperature project, reported in the last issue of the Newsletter). The second involves the installation of *in situ* temperature loggers, which continually monitor a small number of selected sites. Such assessments, however, have been limited by sparse sampling in both space and time using submerged temperature-recording sensors. In the Puget Sound region, for example, the State of Washington relied on periodic data collected at 76 stations to assess water quality conditions for 12,721 km of streams and rivers (i.e., one station for every 167 km of stream).

Continued on page 9

BRIEF SUMMARIES OF SOME CURRENT AND UPCOMING PROJECTS

(from page 8)

Differences in the spatial temperature fields generated using these two methods in the Soos Creek watershed are being explored to assess the adequacy of these alternative methods for representing system-wide stream temperatures. When combined with knowledge of regional geology and land use, it is possible to evaluate the adequacy of the temperature logger network to represent the actual patterns of stream temperatures in the basin. In the Soos Creek watershed, the logger network fails to capture a region of the lower reaches of Big Soos Creek where groundwater recharge keeps stream temperatures cooler than predicted from simple extrapolation of upstream temperatures. Geologic mappings of the region demonstrate that this condition is well-correlated with the presence of glacial outwash, which transmits cool groundwater to the channel.

As yet another alternative to these on-site methods, we are evaluating the utility of remotely sensed thermal infrared (TIR) and visible images of streams and stream corridors for increasing the data coverage for stream temperature analysis and assessment. If stream temperatures can be estimated from images with known and acceptable levels of confidence, then regional temperature assessments will be less sensitive to the uncertainty associated with sampling temperature at a relatively small number of ground stations. Stream temperatures, energy and water fluxes are monitored to evaluate their significance to the stream energy balance using a ground-based network of temperature data loggers, stream gauging stations, and meteorological observations. Logger temperatures have been interpolated between locations to produce hourly maps of the distribution of stream temperatures in the Green River. Thermal infrared images from the satellite based ASTER imager and the plane-based MASTER imager collected in August of 2001 for the Green River are still being processed to obtain stream temperatures; however, images of raw brightness values are used to demonstrate the potential of both thermal imagers to view regional streams.

The Seattle-Area Geologic Mapping Project

Kathy Goetz Troost, Research Scientist

The goal of this project, now starting its fourth year, is to develop a publicly accessible, comprehensive geologic database and new geologic maps to support further scientific study, hazard assessments, and land-use applications across the Puget Lowland. Through initial collaboration with the U.S. Geological Survey and the City of Seattle, a comprehensive mapping project was conceived that includes state-of-the-art data compilation, data display, and geology; a basis for hazard maps and other derivative maps; efficient agency and public data access; and a host of new geologic maps in Seattle (at a scale of 1:12,000), the Tacoma area (1:24,000), and north King/south Snohomish counties (1:24,000). Since the first work began on this project it has continued to expand, most recently through the participation of King County Department of Natural Resources and the cities of Bothell and Bellevue. Its applications

are already beginning, particularly in the evaluation of landslide hazards, groundwater movement, and stormwater infiltration potential.

Geologic mapping in urban areas poses a conundrum: little bare ground is available for inspection, but subsurface data, primarily in the form of geotechnical explorations, are abundant. Most of these data, however, are widely scattered and poorly organized in building and utility departments, transportation agencies, and private consulting firms. Through this project, we have developed and are now populating a GIS-based relational database to efficiently store, manipulate, and display the vast amount of existing subsurface geologic data across the Seattle area to enhance and facilitate the creation of geologic maps.

To date, geologic data from over 30,000 field explorations, exposures, and excavations have been entered into the database. Partnerships have been formed with a number of local public agencies (such as building departments, public utilities, port authorities, transportation agencies, and natural resource departments) both to acquire the raw data from geologic and geotechnical studies and to return the populated database and GIS interface to those agencies. Through these partnerships, the information is readily available to engineers, planners, and the public, identifying locations where non-proprietary geologic data can be reviewed to improve subsequent investigations in the vicinity of existing studies. Several private consulting firms have also provided nonproprietary information.

Data is entered into the database through customized ArcView and Microsoft Access interfaces in two phases, spatial and nonspatial. Spatial data, such as document areas (polygons) and exploration points, are entered through an ArcView interface along with their associated attributes. Once the spatial data has been recorded, nonspatial data, such as the information about each individual geologic layer, are entered through customized Microsoft Access forms. Guidelines have been developed to ensure that the data is entered in a uniform and consistent manner, even though every boring log displays information differently because the logs are prepared by many different consultants and agencies.

Customized tools have also been developed to facilitate the visualization and interpretation of raw data by interactively viewing subsurface geologic data through a series of dialog boxes. Layer data for specific exploration points can be retrieved and subsequently assigned a geologic interpretation along with related data such as confidence, interpreter, and basis for interpretation. A tool has also been developed to generate cross sections at user-specified locations "on the fly" to better understand the stratigraphy of the surrounding area. The results gathered from these tools are being used to better delineate the geologic units and facilitate creation of geologic maps, the first of which are within a few months of publication by the U. S. Geological Survey. ❖

Continued on page 9

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

**Professional Development Opportunities
Fall 2002 Course Calendar**

Wetland Ecology and Land Use Implications

September 18 and 19, 2002 • UW Bothell Branch Campus
Optional field trip: Friday, September 20, 2002

**Fundamentals of Urban Surface Water
Management**

September 25 and 26, 2002 • Seattle

Stormwater Treatment by Media Filtration

October 17 and 18, 2002 • Seattle

Mentoring and Coaching Workshop -NEW-

October 22, 2002 • Seattle

Achieving Real Success as a Project Manager

October 23 and 24, 2002 • Seattle

**Biofiltration and Bioretention for Stormwater
Runoff Quality Enhancement**

November 7, 2002 • Seattle

Effective Project Negotiation Skills

November 13, 2002 • Seattle

**Wetland and Upland Habitat Restoration: Design
Considerations for Increased Success -NEW-**

November 20 and 21, 2002 • Seattle

More information:

Engineering Professional Programs
University of Washington
phone: 206-543-5539 or 1-866-791-1275 (toll free)
fax: 206-543-2352
uw-epp@u.washington.edu

Center members receive a 5% discount on courses. Identify yourself as a member of CUWRM when registering.

Complete course descriptions and registration information are available online at

www.engr.washington.edu/pepl

or call

206-543-5539 or 1-866-791-1275 (toll free)

What's New

We are pleased to announce two new courses this Fall plus an added field trip to one of our existing courses.

Wetland and Upland Habitat Restoration Design

November 20 and 21, 2002 • UW Bothell Branch Campus

This two-day course for habitat restoration professionals provides you with assessment and design tools that improve your ability to translate design concepts into buildable projects with a greater likelihood of success. The class will help those who already have a general understanding of habitat ecology in the Pacific Northwest work in an interdisciplinary design team to develop wetland and/or upland restoration plans with a greater assurance of long-term success. This course is co-taught by Dyanne Sheldon and Susan Buis. Landscape architects, wetland ecologists, biologists, stream ecologists and engineers will find this course of value.

Course fee: \$475 on or before November 6; \$510 thereafter.

**Optional one-day field trip: Wetland Ecology and
Land Use Implications**

September 20, 2002

This course was formerly taught by Rich Horner with Dyanne Sheldon and titled Wetlands Ecology and Protection. The updated course will be taught by Dyanne and now includes an optional field trip. Many of our students view the field trip as an essential component to a course. It gives you an opportunity to see what you learned applied in real life. For this course you will visit several wetland types of the Puget Sound lowlands to identify the physical structure and hydrologic conditions that drive their functions. Sites will be included that illustrate consequences of urbanization on wetland function, including specific design consequences on water quality and quantity from 'typical' stormwater management practices. It is recommended you attend the two days of classroom instruction prior to attending the field trip.

Field trip fee: \$95 on or before September 6; \$115 thereafter.

Mentoring and Coaching Workshop

October 22, 2002 • Seattle

The most frequent request from younger professionals is for a mentor or coach to help them navigate their way through an organization and assist with their career choices and development. This workshop is for individuals and organization leaders who want to improve their mentoring and coaching skills and develop a program to assist others in their professional growth. It covers the key steps of a mentoring program including selecting and matching participants, the phases of a mentoring relationship, and ensuring a successful process. You will observe and practice specific coaching skills, including giving and receiving feedback, motivating performance and handling conflict. This course is taught by Anne Smith. She has recently presented this course to the Nevada Society of Professional Engineers.

Course fee: \$310 on or before October 8; \$345 thereafter.

Publication update of current projects at the Center (with dates of Newsletter articles and available Center publications)

Project	Newsletter Issue	Center Publication
LAND COVER AND IMPERVIOUSNESS Landsat land cover interpretation Infiltrative parking lot surfaces The impact of urban patterns on ecosystem dynamics	Sp 99, F 00 W 96, F 96 Su 01	CUWRM web rpt. & data K19
GEOLOGY AND SOILS Puget Lowland geology and geologic hazards	Sp 97, Su 98	linked web site
STREAMS Urban stream rehabilitation: Riparian buffers in urban watersheds Effectiveness of LWD in rehabilitation projects Sediment budget of mixed-use watershed Rates of stream channel restabilization Urbanization effects on stream biology Metrics of hydrologic change from urbanization Urban Planned Development monitoring: Relationship of turbidity to total suspended solids Monitoring of ephemeral streams Stream habitat assessment protocols Remote sensing of stream temperature Regional, synchronous stream temperature survey	Su 98, Sp 01 W 97 W 00 F 99 Su 99 Sp 00 F 00, F 01 F 99 W 99 W 00 W 02	Final report (on web) CUWRM web report K25 K23 K24 K26 CUWRM web report E17 (on CUWRM web) CUWRM web report & data
WATER QUALITY/CHEMISTRY Water-quality effects of road ditches and swales Urban stormwater management evaluation Highway stormwater treatment testing	F 99, F 00, W 01 F 99 W 00, F 00	G15 (on CUWRM web) G14 (on CUWRM web)
WATER USE, REUSE, AND GROUNDWATER Numerical groundwater modeling of the Duwamish Review of water reuse case studies On-site runoff mitigation by reuse of rainwater	Su 01 W 01	CUWRM web report L1 (on CUWRM web)
REFERENCES Urban Issues Library Salmon in the City conference proceedings	F 99	On CUWRM web site On CUWRM web site



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