The Washington Water RESOURCE

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Message from the Director

In this issue of the Newsletter, we highlight some recent studies and reviews that address one of the problems associated with water chemistry in urban and suburban areas: degraded highway and roadway runoff. The bulk of this work has come to us through the interest of State and local highway and stormwater agencies; it is the precursor to a long-term full-scale test facility that is being installed under the north end of the I-5 Ship Canal bridge in Seattle, and that may actually be operational within two years of its originally scheduled completion date. The Center, under the lead of David Stensel, was involved in establishing the testing procedures and protocols (see the Winter 2000 issue of the Newsletter), and we will be part of the facility's operation as well. The complete texts of this and several other new study reports are available on the Center's web site, http://depts.washington.edu/cuwrm/, where we are progressively moving more of our available publications.

The data collection and compilation is now complete for the third annual Stream Temperature Survey, conducted on August 2th with the help of 98 individuals (see the last issue of the Newsletter). We have compiled the temperatures, flow, and riparian conditions for over 800 separate measurement sites this year, making this the most extensive and systematic of our three efforts to date. A more complete report will be ready in the next few months; some of the preliminary results will be available at this year's Annual Review on October 20 (see accompanying article).

Annual Review of Center Research

On *Friday, October 20th,* faculty and students affiliated with the Center will summarize our results from this last year's research. The presentations will take place from 9:00 AM until 12:00 noon at the Center for Urban Horticulture (CUH), at the northeast corner of the University of Washington campus. The CUH is in a classroom and office complex at the edge of Portage Bay, northeast of Husky Stadium and the Montlake Bridge. To get there drive on SR 520 (Evergreen Point Bridge) towards the University from I-5 or I-405 and take the Montlake Boulevard NE exit northbound, cross the Montlake Bridge, stay straight as you pass the stadium on the right with the main campus on the left. Bear right (with the main flow of traffic) as you pass the large parking lots on the right, and then pass University Village Shopping Center on the left as you continue on NE 45th Street. Past the playing fields (on the right) and Safeway (on the left), turn right onto "Mary Gates Memorial Drive." The road bends left in about 1/4 mile; just after the bend, CUH is on the right with lots of parking just beyond. Parking is free and the room is substantially larger than our space in previous years!

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The Washington Water Resource is the quarterly publication of the Center for Urban Water Resources Management at the Department of Civil and Environmental Engineering, University of Washington, Box 352700, Seattle, WA 98195.

Web address:
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MESSAGE (from page 1)

The schedule of presentations is still being confirmed as this newsletter goes to press, but a partial list of anticipated reports includes:

- Urban Stream Rehabilitation: results from the three-year project
- Further results of the automated land cover classification and watershed impervious-area determinations from LANDSAT imagery—1998 land-cover classification
- Puget Lowland urban corridor geology and geologic hazards
- The third annual snapshot of regional stream temperatures, and remote sensing of stream temperatures
- Biofiltration swale maintenance for water-quality improvement of road runoff
- Review of "ultra-urban" stormwater treatment devices (see article, this issue)
- Physical and biological monitoring of aquatic systems

Derek Booth ❖

Technology Review: Ultra-Urban Stormwater Treatment Technologies

By Christopher C. Brueske, Department of Civil and Environmental Engineering, University of Washington

INTRODUCTION

This document was compiled to provide a review of "ultra-urban" stormwater treatment technologies. "Ultra-urban" technologies are designed to remove pollutants from wet weather runoff in highly developed areas where land values are high and available space is limited. These technologies differ from traditional stormwater treatment methods (e.g., water quality ponds and grass swales) in that they are extremely compact and can be retrofitted into existing stormwater collection systems.

The technologies included in this review were developed primarily to remove suspended solids from urban runoff. Several of the units also include design features to remove oils and other floatable contaminants. Generally speaking, these technologies remove metals, nutrients, and other contaminants only to the extent that these contaminants are adsorbed to suspended solids. A notable exception to this is certain filtration systems, which can be operated with an adsorptive media specific to dissolved metals, organics, and nutrients.

This document examines stormwater treatment units similar to those that will be tested as part of the Environmental Technology Evaluation Center (EvTEC)/Washington State Department of Transportation (WSDOT) Technology Evaluation Project in Seattle, Washington. The units examined are designed to operate "in-line" with the stormwater collection system and provide treatment of stormwater flow on a continuous basis during a storm event. Generally speaking, the units are compact and do not require pumping or other energy input. This document examines in detail the following four types of treatment technologies, categorized according to their underlying solids removal mechanism:

- Gravity separation
- Swirl concentration
- Screening
- Filtration, combined in some cases with dissolved contaminant removal by an adsorptive medium

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For each of these categories, the following information is provided:

- Detailed examination of one or two representative trademark units to illustrate the treatment mechanism
- Summary of hydraulic principles involved in the treatment mechanism
- Literature review, including a summary of reported treatment performance data

The full report also examines issues associated with monitoring stormwater treatment units, including the following:

- Examination of both "storm event mass-based" and "hydrology-based" methodologies for calculating removal efficiency
- Summary of a proposed protocol for evaluating new stormwater treatment technologies, developed specifically for the Puget Sound region by the Stormwater Managers Committee of the Washington Chapter of the American Public Works Association (APWA)

The appendix (of the full report: G14) provides a list of contact information for manufacturers and vendors of stormwater treatment units similar to those examined in this paper.

APPLICATION OF TECHNOLOGY REVIEW FINDINGS

The following section applies the findings of the technology review to develop an example design protocol. This protocol is intended to illustrate the factors that must be considered when selecting and sizing an "ultra-urban" stormwater treatment unit. It also illustrates data limitations that complicate and add uncertainty to the selection and design of a treatment unit. In addition to the design steps presented below, individual technology vendors may have additional data requirements and design steps that should be considered.

The following design protocol does not address the motivation for providing treatment to a specific stormwater source. There are numerous reasons why stormwater treatment may be required, primarily related to compliance with local, state, or federal water quality regulations. Full consideration of these factors is beyond the scope of this paper; therefore, the protocol outlined below assumes that a decision has been reached that improvement of the water quality of a specific stormwater source is necessary.

Design Step 1: Characterize the Source

It is necessary to understand both the hydrology and the pollutant loads of the stormwater source. When selecting an "ultra-urban" treatment unit, the peak flow rate, rather than the total runoff volume, is the most important hydrologic parameter. The peak flow rate can be determined by a standard hydrological evaluation such as the rational method, in which runoff flow rate is calculated based on the intensity of rainfall, the size of the drainage basin, and the basin land use (for example, the amount of impervious surface). Runoff flow rates should be calculated for rainfall intensities associated with various design storms, such as the 3- and 6-month and the 1-, 2-, 5-, 10-, and 100- year return period storms. To check the hydrology calculations, flows should be monitored at the point in the stormwater conveyance system where the treatment unit will be installed. A comparison of flow in the system to rainfall intensity for several storms will allow calibration of the hydrology evaluation. The end product of the hydrology evaluation is a table of peak runoff flow rates associated with several different design storms.

Water quality evaluations are necessary to characterize the type, concentration, and variability of pollutants in the stormwater source. Analyses that may be conducted, depending on water quality and regulatory issues, include TSS, metals (dissolved and total), and nutrients. In addition, the results of this technology review suggest that settleable solids and particle size distribution analyses should be conducted. Water quality samples should be collected during different portions of the storm hydrograph; specifically, samples should be collected during the onset of runoff, during the rising limb of the hydrograph, and during the period of peak runoff. This will determine how contaminant concentrations vary during the course of a storm. Sampled storms should be preceded by an antecedent dry period of 2-3 days to allow for pollutant build-up in the drainage basin.

Design Step 2: Determine Treatment Goals

Specific treatment goals will depend on the regulations motivating the installation of the stormwater treatment unit. Two types of treatment goals are possible. The first is based on achieving a specific water quality goal, such as an 80% reduction in TSS. This type of requirement for mass reduction based on a percent of the influent contaminant load is typical for stormwater applications. As discussed in Section 6 (of the full report: G14), stormwater BMPs have been required to achieve 80% removal of TSS, but specific methods to measure this removal efficiency have not been formalized.

A second type of treatment goal is to achieve *some degree of treatment* for a specific design storm. For example, the Washington State Department of Ecology's 1992 *Stormwater Management Manual for the Puget Sound Basin* requires that a BMP be used to provide treatment for flow up to the 6-month, 24-hr return period. However, there is not an associated water quality treatment goal for this requirement. It is important to note that these two types of treatment goals are not necessarily mutually exclusive. For example, it is possible to have a requirement to achieve 80% TSS reduction for all storms up to a design storm. In addition, if source characterization (Design Step 1) indicated that the majority of pollutants are carried during the initial stages of a storm, it may not be neces-

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sary for a treatment unit to treat the peak flow of a design storm to achieve a significant mass-reduction in pollutants. The research conducted for this technology review indicated that there is currently no clear consensus on what appropriate treatment goals should be applied to stormwater treatment units.

Design Step 3: Identify Site-Specific Constraints

Several site-specific factors must be considered for the location in the stormwater conveyance system where a treatment unit is to be installed. First, it is necessary to determine whether the unit can be installed in a parallel arrangement with the main stormwater conveyance system so that only flows up to the unit's design flow are diverted into the unit. Flows in excess of the unit's design flow remain in the conveyance system and bypass the treatment unit. Vortechnics™ Inc. refers to this type of installation as "off-line." Hydraulic modeling shows that diverting flows only up to the 3-month storm event to a treatment unit still can result in treatment of 93% of the total volume of stormwater over a 100-year period. The recommendation to treat smaller, more frequent storm events and bypass larger, infrequent events, was noted in this technology review several times. This type of installation allows better control of the hydraulic application rate (HAR) and an increased ability to achieve consistent treatment. It also permits the use of smaller, less expensive treatment units.

If site conditions are such that the unit must be installed directly in the conveyance system, it must be sized to convey the maximum design storm for the stormwater conveyance system (for example, the 100-yr return period storm). It is important to note that all of the units reviewed include an internal bypass, whereby peak flows are routed through the unit with minimal treatment. In some cases, however, internal bypasses have the potential to allow resuspension and export of sediments from a treatment unit.

Another site-specific constraint that must be considered is the available hydraulic head at the point in the stormwater conveyance system where the treatment unit will be installed. "Ultra-urban" treatment units are designed to minimize head requirements; however, it is necessary to contact a technology manufacturer in order to ensure that sufficient head is available for each application. Finally, the availability of electricity at the installation site should be considered. Although none of the units reviewed require electricity to operate, electrical power may allow process modifications or the installation of automated monitoring equipment.

Design Step 4: Select Treatment Unit

Selecting a specific treatment unit is perhaps the most difficult step in this design protocol, due primarily to a lack of performance data that can be compared between units. Based on research included in this technology review, all of the units are capable of achieving some degree of water quality improvement; however, it is not possible to determine which units are most effective. Of the data that have been reported for these units, much of it was collected under laboratory conditions with synthetic stormwater. Data from field applications do exist, as reported in this technology review, but tests of various units under standardized conditions of flow and pollutant concentration have not been conducted. Without sound comparative data, only a few general observations can be made to compare the performance of the treatment units included in this technology review:

- Only the Stormfilter™ system addresses the removal of dissolved metals, nutrients, and organics.
- Stormfilter™ cartridges equipped with a 30-mm pleated fabric insert may be most effective at capturing fine and non-settleable solids, although specific data on this was not located.
- All units except CDS® include hydraulic controls to trap floatable debris and oil. CDS® has a physical control that captures floatable debris larger than the screen aperture size, and sorbents can be added to capture floatable oils.
- Due to the presence of secondary flows that augment gravity separation, swirl concentration technologies are conceptually capable of achieving a higher degree of treatment than technologies that are based strictly on gravity separation; however, no comparative data was located to verify this.
- A CDS® unit may be better suited for a stormwater source that carries excessive amounts of gross trash and debris than for a stormwater source with a high concentration of fine particles.

In the event that a CDS® unit is selected, it is necessary to select the screen aperture size, based on the particle size distribution of the stormwater. Also, if a Stormfilter™ unit is selected, the appropriate media must be chosen to obtain the treatment goals. In the absence of comparative performance data, the final selection of a treatment unit may be based more on cost (capital and maintenance) and other site-specific factors such as available space and hydraulic head.

Design Step 5: Size the Unit

Once a specific treatment unit is selected, correct sizing of the unit is essential to obtain reliable water quality improvement. The data from Design Steps 1-3 must be evaluated to address the following specific design issues and to properly size a treatment unit:

- What is maximum flow rate to be treated? This flow rate may correspond to the peak flow rate from a de-

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sign storm, or to a "first-flush" flow rate (i.e., the flow rate from the rising limb of a storm hydrograph that carries the majority of pollutants for that storm).

- What HAR should be used to achieve the treatment goals? Relationships between removal efficiency and HAR were reported in this technology review for Vortechs™ and Downstream Defender™, and the Stormceptor® model can produce similar data for different sized units. Data similar to these are needed for other units to determine what size unit will achieve the treatment goals for the design flow rate. In addition, the effect of influent concentration on removal efficiency must be considered. For swales and wet ponds, removal efficiency is observed to increase with increasing influent concentration; however, no similar relationships were located for "ultra-urban" technologies. This data limitation adds uncertainty to the process of sizing a unit to achieve a specific treatment goal.

Well-documented relationships between HAR and removal efficiency for various influent concentrations would provide a designer with valuable tools to size an "ultra-urban" unit; however, in lieu of such data, the designer and the technology manufacturer must work together to select an appropriately-sized unit. Technology manufacturers have specific procedures that are employed in sizing a unit, many of which were discussed in this review. However, it is necessary for the designer to be aware of those factors outlined above when working with a manufacturer to ensure that the project goals are met.

Summary and Conclusion

Based on the technology review of "ultra-urban" stormwater treatment technologies presented in this paper, the following conclusions are drawn:

1) Solids removal efficiency for several treatment units was observed to decline with increasing hydraulic application rate (HAR) and with decreasing particle size. No studies were found that reported substantial removal of particles smaller than 30 microns. Particle size distribution and settleable solids analyses should be undertaken as part of an analysis of the capability of an "ultra-urban" treatment process. For stormwater with high concentrations of fine or non-settleable particles (i.e., < 30 mm), "ultra-urban" technologies may not achieve acceptable performance.

2) There is insufficient performance data for "ultra-urban" treatment processes to develop a rational design approach that can be used for all treatment units. HAR is a fundamentally mechanistic design parameter but is currently used only on a limited basis. Well-documented relationships between removal efficiency and HAR are needed to guide the selection and sizing of treatment units.

3) A design methodology that uses a peak flow rate based on a design storm event and HAR versus treatment efficiency relationships would provide a rational design basis for "ultra-urban" treatment technologies.

4) There is a lack of data relating the effect of influent concentration on removal efficiency for "ultra-urban" treatment units. This adds uncertainty to the sizing of a unit to achieve a specific treatment goal.

5) There is a need for a streamlined process by which "ultra-urban" technologies can be evaluated for their equivalency to existing BMPs. The time and expense associated with the proposed APWA protocol may deter technology manufacturers from attempting to demonstrate BMP equivalency. Further, treatment performance should not be the only factor considered when comparing "ultra-urban" technologies to traditional stormwater treatment technologies such as wet ponds and swales. "Ultra-urban" units can provide treatment in locations where the installation of traditional technologies may not be possible due to a lack of available space. This advantage should be recognized in any protocol designed to assess the equivalency of "ultra-urban" units. ❖

A Survey of Ditches Along County Roads for Their Potential to Affect Storm Runoff Water Quality

By Shanti Colwell, Richard R. Horner, Derek B. Booth, and Dalius Gilvydis, Center for Urban Water Resources Management, University of Washington

RATIONALE AND SCOPE

Twenty years of research have demonstrated that the water quality of stormwater runoff can improve after flowing in a well-vegetated channel, relatively slowly, at a depth below the vegetation height. These channels are commonly called "biofiltration swales." Roadside ditches that are vegetated also may have the potential to provide the same water quality benefits as biofiltration swales by removing pollutants. Conversely, ditches that are devoid of vegetation are subject to erosion and could be significant *sources* of sediments and other pollutants. If the potential benefits are to be realized, and the pollutant source avoided, ditch condition and maintenance must be consistent with not only conveyance but also water-quality objectives.

Because no systematic data have been collected that describe ditch characteristics with respect to water-quality considerations, Snohomish and King counties commissioned the Center for Urban Water Resources Management to evaluate ditch status in the two jurisdictions and to consider how road maintenance crews might maximize their potential for water-quality performance. The goal of this investigation was to develop strategies for improving runoff treatment and reducing

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SURVEY OF DITCHES (from page 5)

downstream sediment loading from existing ditches, while retaining their hydraulic function of conveying roadway runoff. The principal focus was to guide maintenance actions, but it was anticipated that design of future ditches should also benefit.

This report documents one aspect of the investigation—a systematic survey of ditches during the summer and fall of 1998, designed to evaluate the water-quality performance of ditches in the two counties' road networks. The survey encompassed 113 ditch segments in Snohomish County and 87 segments in King County, ranging in length from 200 to 600 feet. Single-family residential is by far the dominant land use in the catchments adjacent to the ditches surveyed, a circumstance representative of areas in the two counties with roadside ditches. Specific measurements and observations were made at several transects in each ditch, extending across the width and spaced along the length of each segment. In total, 1000 transects were surveyed for this project, emphasizing the data collection and analysis of those factors that were anticipated to be both beneficial and detrimental to improving water quality.

SURVEY RESULTS

The surveyed ditches have a number of characteristics that should promote pollutant reduction and reduce the tendency of the ditch itself to become a pollutant source. Most ditches have a U-shaped profile (94 and 92 percent, respectively, in Snohomish County [SC] and King County [KC]). This geometry tends to spread flow and reduce velocity, thus helping to limit erosion and advance treatment. Ditches generally have a gradual slope along the direction of flow (mean of 1.9 percent in SC, 1.7 percent in KC), which also contributes to free flow with only moderate velocity. Many of the common causes of vegetation mortality were observed only infrequently: significant erosion, sediment deposition on vegetation, shading, and herbicide applications.

The types and stature of the dominant vegetation observed tend to promote pollutant removal. Fine, close-growing material, either grasses or mixed herbaceous plants, made up most of the vegetation communities. For example, grasses were present in 72 percent of SC ditch bed transects and 50 percent in KC; and other herbaceous growth was present in 34 percent of SC transects and 31 percent in KC, often in combination with grasses. Where vegetation grew, it was generally both relatively high (mean heights of 9.3 and 8.0 inches in SC and KC, respectively) and erect (55 and 51 percent erect, respectively).

Despite the existence of a number of factors *favorable* to water quality, other conditions in the surveyed ditches were not favorable, retarding their ability to remove pollutants and raising the likelihood that they are presently acting as pollutant sources instead of sinks. Rocks and gravel, not a good base for herbaceous plant growth, are fairly common (found in 32 percent of SC transects and 57 percent in KC). Standing water, which harms many grasses with low tolerance of persistent wetness, occurred in 27 percent (SC) and 28 percent (KC) of the observations. Both conditions were commonly associated with low plant cover. Mowing ditches without removing grass clippings was evident in SC (35 percent of cases), although much less so in KC (11 percent). There appeared to be some association of clipping accumulations with reduced plant cover. In addition, nutrients in decomposing plant tissues would be expected to dissolve in runoff and travel to receiving waters (although no downstream sampling has been done in this region to test the importance of this process). On the other hand, litter, while unsightly and common (69 and 67 percent of SC and KC transects, respectively), did not appear to compromise vegetation cover or condition.

Structural measures that avoid erosion and improve vegetative treatment are rare in the area's roadside ditches. Most ditches (about 75 percent in both counties) only received sheet flow from adjacent road surfaces without an upstream point discharge. Of those fed at a single point, only about one in 12 in SC and one in six in KC had any form of energy dissipation or flow spreading (uniformly rip-rap). None of the surveyed ditch segments had any check dams.

Whereas gradual longitudinal slopes limit velocity and help prevent erosion, the grades were so slight (<2 percent) in most of the surveyed ditches that the inverse problem of standing or poorly draining flow was relatively common and did limit vegetation growth. Side slopes averaged about 2:1 (horizontal:vertical), but many were steeper and hence an erosion risk.

In general, the single most important factor in achieving runoff treatment and preventing ditches from becoming sediment sources is thorough, uniform cover by fine, dense vegetation. While the *types* of vegetation were usually favorable, their overall coverage and health were much less so. In Snohomish County, 54 percent of ditch bed transects had 95-100 percent vegetation cover (and 25 percent had 70-95 percent coverage). However, this was true in only 18 percent of KC transects (and 15 percent with 70-95 percent coverage). Indeed, more KC ditch beds had <5 percent cover (36 percent) than ≥70 percent cover (33 percent). However, only 21 and 23 percent of the SC and KC bed plants, respectively, were rated as "healthy." Therefore, the combination of full or nearly full cover of healthy growth was rare (12 percent on SC beds and 11 percent on KC's). The main cause of poor health was drought (55 and 44 percent of SC and KC bed transects, respectively), but standing water was also quite common as a cause.

RECOMMENDATIONS FOR MANAGING TO IMPROVE WATER QUALITY

The recommendations growing out of the survey to improve water quality benefits and attenuate ditch pollutant sources fall into two categories—those practices that are currently being followed to good effect, and that should be continued (or applied more universally); and those new practices that would likely produce good results.

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SURVEY OF DITCHES (from page 6)

Continuation of Existing Practices

1. In future roadside ditch site selection and design continue to avoid heavy shading and steep slopes. Continue to use U-shaped ditch profiles.
2. Make side slopes no steeper than 3:1 (horizontal: vertical), if possible, and never steeper than 2:1.
3. In new designs where high flow velocities could occur, regulate velocity at the point inlet, if any, using an energy dissipater (e. g., rip-rap pad) and within the channel using check dams (see biofiltration guidance in the King County Surface Water Design Manual for specifics).
4. Remove large woody growth before it has an opportunity to damage or take space from finer growth that makes a better treatment medium.
5. Continue to avoid herbicide applications that damage ditch vegetation.

Recommended New Practices

1. Design point inlets of new ditches to distribute flow across the full width using a flow spreader.
2. Retrofit existing ditches having evidence of channelized, incising flow with energy dissipaters, check dams, and/ or flow spreaders.
3. If a poor growth medium, especially rocky soil, is present, over-excavate the poor medium and replace with more favorable soil.
4. Attempt to avoid standing water by siting ditches where high water table is not likely, sloping at least 2-3 percent if possible, and carefully grading to avoid low spots. If high water table is likely to produce persistent wetness, establish wetland growth as the dominant plant community rather than grass.
5. Specify and plant a mix of grasses and other fine, close-growing herbaceous plants, including wet-tolerant and drought-tolerant species.
6. There may be aesthetic and other operational reasons for mowing. Environmentally, there is not enough evidence, at least at this time, to support any specific recommendations on large-scale mowing of roadside ditches for water pollutant reduction. However, residents often mow ditches in the public right of way; they should be educated, and if necessary required, to collect and dispose of their clippings in a manner that does not harm the vegetation nor release nutrients from decaying vegetation into stormwater runoff.

In summary, most physiographic conditions are generally favorable for achieving some water-quality function from the region's roadside ditches. Roadway and hillside gradients are moderate, the volume and velocity of most flows are not highly erosive, and the road-related drainage network does not generally concentrate large discharges into the head of ditch segments. Yet other conditions are less favorable, particularly the lack of rainfall in August and September and the common occurrence of seasonally high water tables in the winter and spring. A reasonable suite of design and maintenance practices should maximize the potential for water-quality improvements with little or no change in current operations and design (or, at least, the current *standards* for operations and design). Yet certain intrinsic factors, particularly high water tables or overly well-drained soils, will likely render roadside ditches ineffective for water-quality improvement in certain parts of these counties. Where such unavoidable conditions are recognized, such structural measures as flattened side slopes, energy-dissipation pads, and check dams should receive additional attention to help compensate for the likely absence of vegetation over the long term. ❖

Fate & Transport of Nonpoint Source Metals: Design of Highway Runoff Detention Ponds

By David Yonge, Professor of Civil Engineering, Deptartment of Civil and Environmental Engineering, Washington State University, Pullman, Washington

Interest regarding the impact of highway runoff on the environment was initiated in the mid 1970's. Several studies have been conducted over the years to define both the type and concentration of pollutants in the highway runoff. Recently, studies have been initiated to define and evaluate the cost-effective means of removing pollutants in highway runoff. Evidence suggests that storm detention ponds, which exist in large numbers in the US, may effectively detain pollutants of concern. Because these highway runoff detention ponds already exist, they could be a cost-effective "best management practice" or BMP for pollution detention. Consequently, information that quantifies their effectiveness is desirable. This information could then be used as a basis for the development of detention pond design and operating criteria.

A 30-month field and laboratory research project was initiated in the summer of 1996. Three wet pond sites were selected, in both eastern and western Washington, that covered a wide range of average daily traffic (ADT) and annual rainfall patterns. Pond volumes are about 2 watershed-cm (i.e., the depth of a pond if its volume were spread over the entire watershed area), more voluminous than most residential-area detention ponds constructed in central Puget Sound during the 1980's and similar to those constructed during the 1990's. Wet pond in-

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fluent and effluent data were collected for numerous storm events and monitored for constituents that included metals (Cd, Cu, Pb, Zn), PAH, suspended solids, COD, and nutrient concentrations as well as toxicity. Pond water column and sediment samples were collected quarterly and analyzed for the constituents in addition to chlorophyll (water column) and particle size distribution (sediment). A scale model (1:12) of one of the wet ponds was used to measure the pond hydraulics as a function of different inlet/outlet configurations. These data are currently being evaluated and will be applied in the development of a decision support system that can be used to design wet ponds and predict pollutant retention in existing ponds.

The data indicates that stormwater quality is highly variable and can be dependent upon antecedent dry period, traffic density, and regional rainfall patterns. Contaminant detention is directly related to the sedimentation rate for those constituents that partition onto stormwater solids and can be predicted by application of known partition coefficients and Type I settling theory. Nutrient removal exhibited first order kinetics with slow reaction rates relative to the pond detention time during storm events. Metals partitioning was found to be inversely proportional to particle size and to be highly variable in both the wet pond inlet and outlet. Although PAH's were often detected in the pond influents, no concentrations above the detection level were observed in the pond effluents.

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

Project	Newsletter Issue	Center Publication
Urban stream rehabilitation:	Su 98	
Riparian buffers in urban watersheds	W 97	
Landsat land cover interpretation	Sp 99, W 00	E16 (on CUWRM web)
Regional, synchronous stream temperature survey	Su 98, F 98	CUWRM web data
Effectiveness of LWD in rehabilitation projects	W 00	K25
Sediment budget of mixed-use watershed	F 99	K23
Rates of stream channel restabilization	Su 99	K24
Urbanization effects on stream biology	Sp 00	K26
Urban Planned Development monitoring:	F 99	
Relationship of turbidity to total suspended solids		
Monitoring of ephemeral streams		
Infiltrative parking lot surfaces	W 96, F 96	K19
Stream habitat assessment protocols	W 99	E17 (on CUWRM web)
Puget Lowland geology and geologic hazards	Sp 97, Su 98	linked web site
Water-quality effects of road ditches and swales	F 99, F 00	G15 (on CUWRM web)
Urban stormwater management evaluation	F 99	
Urban Issues Library	F 99	On CUWRM web site
Highway stormwater treatment testing	W 00, F 00	G14 (on CUWRM web)
Remote sensing of stream temperature	W 00	
The impact of urban patterns on ecosystem dynamics		

Human Behavior in Urban Riparian Corridors

By Sally Schauman, Emeritus Professor of Landscape Architecture, University of Washington (sebring@u.washington.edu)

INTRODUCTION

In Pacific Northwest urban/suburban riparian corridors, managers spend energy and resources on restoration or rehabilitation work to improve aquatic resources. Multiple dilemmas face managers, but they fall under two general challenges: 1) how to select those corridors that have the best potential for rehabilitation, and 2) how to predict the conditions or forces that will ensure that self-sustaining rehabilitation over time. To provide insights to these challenges, a multi-disciplinary University of Washington team studied certain Puget Sound lowland streams for the past three years in an effort funded by the EPA and NSF's Waters and Watersheds Program. The first challenge is primarily addressed by an analysis of the physical, biological and social conditions; however, understanding the specifically social context of stream rehabilitation is fundamental to addressing the second. This paper reports component studies addressing the second challenge.

The social context is often the professional realm of environmental planning, frequently a responsibility of urban planners or landscape architects on a multi-disciplinary team. Unfortunately, these professionals must work with incomplete scholarship and changing notions about community involvement. Only a scant amount of research has been on human perceptions of riparian landscapes in general and even less on human behavior in the riparian context (Kaplan and Kaplan, 1989). After studying environmental decision-making worldwide, anthropologist Eugene Anderson (1996) argues that people act using partial truths, emotions and faulty memory, then rationalize their environmental behavior after the fact. Anderson's suggestion may be applicable to urban riparian systems, for we know little about people's actions in these landscapes. Importantly, almost no research has been done to establish a connection between public participation or education and the success of aquatic habitat rehabilitation.

Nonetheless, what often occurs is that when community involvement becomes broad, well organized, and vocal, this activity shapes political processes to continue rehabilitation without regard to the physical or biological potential of an urban/suburban stream. From only a biological perspective, such systems commonly have low potential for full aquatic species rehabilitation but they do have a high potential for rehabilitation as a valuable and needed urban open space. As such they richly deserve public attention and dollars. However, justification for public expenditures primarily for aquatic species rehabilitation, such as salmon recovery, seems less reasonable. This also illustrates how commonplace it is for most environmental planning resources and energies to be focused on groups, not on individuals. A primary focus of this study was to explore the nature of the behavior of individual people in riparian corridors.

INDIVIDUAL BEHAVIOR TOWARD STREAMS

We structured our study around 2 questions: 1) How do individuals affect streams in their backyard? 2) Is this individual behavior toward streams broadly predictable? We focused primarily on individual behavior rather than on attitudes or opinions because we agree with Anderson (1996): people will not necessarily do as they profess. Thus, rather than surveying attitudes and then inferring behavior, we started with behavior. To scope out how individual behavior might routinely affect streams in the greater Seattle area, we queried an "expert" group in July 1997. After compiling 98 names of people who had day-to-day responsibilities for streams, we selected 18 who represented geographic and professional diversity. This group included stream stewards, biologists, maintenance crew members, and engineers. The central question posed to the 18 experts in face-to-face interviews was, "From your personal knowledge what types of individual behavior takes place in the riparian corridor?" We then mailed questionnaires to 60 additional experts. Nineteen (32%) responded to our mailed survey.

From the responses we created a typology of 46 different behaviors—39 degrading activities (85%) and seven positive activities (15%). These data were analyzed spatially to determine if any actions could be grossly attributed to location factors. Actions such as buffer clearing seems to be happening in all areas although the reasons varied; dumping occurred everywhere but was cited less frequently where housing prices were higher.

Because the results were overwhelmingly negative we resurveyed 19 experts, of whom nine (50%) replied to the resurvey. All believed the negative results were accurate and believed the major causes were the public's ignorance of biology, connections between stream and human health, and cumulative impacts. One respondent echoed the rest—"people think first of their personal, financial or aesthetic concerns and what the stream needs secondarily." Even ardent conservationists mostly fall into this group. Only three experts believed regulations were a solution, while the most mentioned solutions were to encourage individual stewardship, to increase knowledge on how individuals can make a difference and to increase biological education for the public.

Our premise is that these individual behaviors are not always rational or conscious. We speculate that we can understand the origins of the actions by broadly categorizing behaviors in the riparian corridors and then tracing backwards into an individual's personal history. We hope to find common threads in these personal histories that could enable agencies to direct specialized educational efforts. The experts' opinions partially answered the first study question: individual degrading behavior toward streams is more pervasive than positive behavior. In order to answer the second question (is individual behavior in stream corridors broadly predictable?), a more general theory of individual behavior in the landscape is needed.

Continued on page 10

URBAN RIPARIAN CORRIDORS (from page 7)

THEORY OF INDIVIDUAL BEHAVIOR IN THE LANDSCAPE

One reason environmental planning has focused on groups rather than individuals is because, until recently, it has been reasonable to assume that individual behavior in the landscape was not broadly predictable. This assumption is now arguable given the past three decades of research by environmental psychologists, biologists, social scientists, landscape architects, planners and geographers. To better understand the aesthetic dimensions of the landscape, planner Bourassa (1991) suggests that all human landscape experience is a combination of biological, cultural, and personal experiences. It seems reasonable to explore these three factors as one way of evolving a theory to explain individual human behavior in riparian landscape.

Biology. Yale professor of social ecology Stephen Kellert (1997) and Harvard biologist, E. O. Wilson (1993) believe human biological connections to the landscape exist. Geographer Jay Appleton (1994) categorized these connections as a universal human need for "prospect, refuge and hazard" opportunities in natural landscapes. Environmental psychologists Rachel and Stephen Kaplan (1989) found that people will instinctively, but consistently, prefer landscapes that have natural rather than built features, smooth ground planes, climbable trees, invite participation but are not monotonous, and have a sense of non-threatening mystery. These theories and results partially explain why there seems to be a universal appeal for green pastoral landscapes with lawns and large shade trees, such as those typically found in American suburban parks. Our hypothesis is that the majority of individuals we survey will already hold similar "green" opinions, professing ecological attitudes more often than other choices.

Culture. Biology may explain a basis for general human behavior in the landscape, but it does not fully explain individual actions. Another premise of this study is that an individual's perceptions, and ultimately her/his behavior in the landscape, is modified by cultural factors at two scales. One scale, the largest, is the overall mindset of a community such as a region or a neighborhood. For example, salmon have become THE Pacific Northwest mascot representing a desirable environmental quality of life and an icon for the movement to improve water quality. The regional mindset that salmon are beloved is overwhelming; few individuals living in Seattle would easily admit to not caring about this sacred icon. The culture of a neighborhood can also influence how individuals behave in the landscape, and in particular how one maintains her/his front yard. Often an unspoken neighborhood norm or explicit deed covenant exists regarding the level of care or amount of lawn along a street. This study dealt only with backyards of homes along streams, areas where an individual or a family can more likely modify the landscape with less regard for neighborhood appearance standards.

The second scale of cultural factors involves specific influences on individuals, including education, childhood contact with nature, adult activities in natural landscapes, travel, and religion. In other words, a person is influenced not only by group factors (regional, neighborhood) but also by factors that are unique to an individual's life. We believe that if similar patterns of behavior can be found, then these may be generally attributable (in future studies) to an individual's cultural experiences that s/he may share with others.

Personal Experience. It seems reasonable that an individual will behave in the landscape at any given moment based on a combination of biology, community cultural mindsets, and her/his personal experiences. Our premise was that in home backyards all these factors work together to influence how a person modifies or maintains her/his landscape. We studied single-family detached residences on varying lot sizes and not in gated communities. We expected to find unique, but broadly predictable, individual behaviors in backyard landscapes that fit within general analysis categories.

INVESTIGATION OF HUMAN BEHAVIOR IN THE LANDSCAPE

We investigated three categories of behavior: ecological care, personal space, and personal place. We hypothesized the first category, ecological care, represents both a biological connection to the environment and a regional mindset regarding a quality of life revolving around salmon. Although the first phase of our study told us that the experts believed individuals mainly degraded riparian corridors, we thought the results might be skewed because negative behaviors may be reported more than positive ones. We expected to find a wide variety of behavior demonstrating some level of ecological care in backyard activities affecting the abutting stream.

The control of personal space, the second category, represents a neighborhood cultural mindset for typical American suburbs and has been a familiar variable in architectural studies. It has been generally believed until very recently (Shattuck, 2000) that American suburban backyards were places where an individual or a family could make unconstrained landscape choices. Our expectation was that individuals would behave in different ways to mark their territory, but that these behaviors would change as the lot sizes or house prices varied.

The third category, personal place, is an exploratory variable. Little has been theorized about personalized home landscapes although the phenomenon is well recognized. For example, garden competitions always feature home landscapes created with great time and effort to reflect the special artistic, functional, or horticultural needs and visions of the owner (Stahl, 2000). We included this variable to see if personalized landscape designs took the stream into consideration.

METHODOLOGY OF THE BACKYARD BEHAVIOR STUDY

Our study of backyard behavior included mailed surveys, face-to-face interviews, and photographic surveys. A survey was sent to 520 residents who lived along three suburban creeks. To date, 96 (18%) of the surveys have been returned. A similar survey was also sent to 298 residents who did not live along the creek but lived in nearby neighborhoods, and to date, 54 (18%) have been returned. The survey asked the respondents to rate "how important" (on a 5-point scale) each of 12 landscaping goals was for their backyard "if time and money were not constraints." Additionally, we asked them to list the "three most important considerations" your family takes into account when you make decisions concerning the landscaping, gardening, or other features in your backyard. We also conducted eight face-to-face interviews, asking respondents to describe changes they would make "if time and money were not constraints." Interviewers did not mention the stream.

RESULTS

Our initial analysis shows ecological care did rate higher than personal space or personal place, but the differences between the mean values for the three categories were not statistically significant. In response to the question, "What are the three most important considerations in the landscaping or gardening?", less than 10% indicated that any ecological considerations were important. These minority responses included "planting native species, salmon habitat, creating song bird habitat, and composting." The overwhelming response (>75%) to this "most important" consideration was "low maintenance." Many respondents repeated this 3 times on their survey.

The face-to-face interview data are yielding perplexing results. Seven interviewees made no mention of ecological care they had given the stream. Only one individual interviewed so far had purposefully cared for the stream corridor ecology. This man's backyard had no lawn and he had cut no vegetation. By contrast, another interviewee bragged to us about how he had ignored the buffer regulations, cut all vegetation and had lawn to the stream edge. We did an in-depth follow-up interview with these two individuals, both of whom were retired men living alone. After an extensive questioning on education, family, hobbies, habitats, previous occupation, only three differences between them emerged. The one who cut all the vegetation was 15 years older than the other, had hunted and fished and was a builder by occupation. He told us repeatedly that nature was for "man to use" and that the "fish didn't mind what he did because they still spawned in his backyard." The other man had never hunted or fished and had held a diversity of jobs during his work years. Both knew little about the biology of the stream. This comparison of 2 respondents proves little, but it has given us insight on how we will analyze the demographic factors in the future.

Photographic surveys are now being analyzed. Preliminary results indicated that riparian buffers remain more intact when protected by a subdivision covenant and a vertical topographical separation between the stream and the backyard of more than 4 meters.

CONCLUSIONS

Tentative answers to our original questions seem to be:

1. Do individual residents degrade or protect riparian corridors in their backyards? The experts believe that individuals degrade. This seems to be generally true because only a small minority is engaged in protection and none so far have demonstrated any individual rehabilitation actions toward the stream. In addition, protection occurs more often when residents respect subdivision covenants regarding the buffer area and their backyards are vertically separated from the stream

2. Is individual behavior in riparian corridors broadly predictable? Thus far, we have been able to attribute all backyard conditions to one of the three categories: ecological care, personal space, and personal place. This leads us to believe that these categories could be used to predict individual behavior in suburban backyards in our study area, although the category of ecological care has the least evidence so far.

We hope to make recommendations regarding stewardship and education programs after all our results have been analyzed. Preliminarily, it seems important to shift some energies and resources from groups toward individuals, for indeed the behavior of individuals in their own backyards adjacent to streams is important.

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