The Washington Water RESOURCE

The quarterly report of the Center for Urban Water Resources Management

Volume 10 ❖ Number 4 ❖ Fall 1999

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Message from the Director

As part of the region's efforts associated with the listing of Chinook salmon under the Endangered Species Act, R2 Consultants have been working with agencies in the Tri-County region (Snohomish, King, and Pierce counties) to compile the existing scientific information on the protection and recovery of salmonid species and their habitats in Puget Sound. Their work is nearly finished, and the resulting library will be housed at the Center as soon as it is available in early January. It reflects one important role of the Center, that of a central and regional archive of urban water resource information, which complements our primary efforts as a center for research into these issues. The library and associated database are described in the adjacent article. We are committed to making the documents in the library available to members of the broader community, be they from governmental agencies, consulting firms, or academia. To that end, we will be establishing a weekly period in which visitors to the University of Washington campus can borrow the materials directly to make their own copies, and we will also accept written requests for copying and mailing of particular documents. The database, which includes summaries of all items and full-text version of some, will be distributed through the Tri-County agencies and should provide a widely available index of all available publications. Please check our web site, <http://depts.washington.edu/cuwrm/>, for more information as soon as it becomes available.

This issue of the *Newsletter* also contains several articles on new, ongoing, and recently completed research at the Center and from related efforts. Many of these results were presented at the Annual Review of the Center's research, held October 15th on the University of Washington campus. We have outgrown our meeting room; with about 120 people in attendance, we will be shifting to larger quarters for next year. We continue to enjoy strong support from the University and from the regional agency and consulting community. We also are seeing an ever-growing range and inventory of research projects.

As befits the season of giving, Center subscription renewals for 2000 will be sent out in January. Subscriptions cover the cost of the newsletter and help support many of the ongoing, cooperative functions of the Center as well. Support from the colleges of Engineering and Forest Resources allow us to maintain the same subscription rates that have been in effect since the Center began in 1990. I also remind you that all are welcome to add additional recipients of the newsletter to your subscription without charge, because our interests are all best served through the broadest distribution of information.

Derek Booth ❖

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.

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Urban Issues ESA Document Library and Database

URBAN ISSUES LIBRARY

Documents and reports relevant to the protection and recovery of salmonid species and their habitats in Puget Sound have been gathered from a wide variety of sources and compiled into the "Urban Issues ESA Library." Included in this library is a broad collection of internal reports, which were contributed by the Tri-County Urban Issues Advisory Committee's technical staff. These reports are now easily accessible to people working on regional ESA recovery efforts. The library also contains documents from federal, tribal, state, and local agencies, as well as scientific articles that were published in peer-reviewed journals.

In general, the documents in the library contain descriptions of salmonid habitat, distribution, and status in the Puget Sound region as well as information on regulations and regional planning that potentially affect salmonid populations. The library also contains a fairly comprehensive collection of documents related to ecological processes, assessment methods, and habitat restoration that are relevant to the protection and recovery of regional salmonid populations. All of the library documents were indexed by the primary author's name for quick retrieval. Each library document also has a matching electronic record in the Urban Issues Document Database.

URBAN ISSUES DOCUMENT DATABASE

The Urban Issues Document Database indexes and summarizes the contents of the Urban Issues ESA Library. It was designed to be an updateable catalog that can be expanded as new research is completed and documents are produced. The document database was developed to provide for easy searching of any or all entries by topics including keyword, author, or title. Currently, the library and its associated data contain over 400 documents.

Documents gathered for the library were assessed for relevance and data quality prior to their entry into the database. The level of relevance to the Tri-County ESA recovery effort is provided in the database to help guide the user who wants to focus on documents that are most useful to the Puget Sound recovery effort. The level of data quality is provided to assist the user in recognizing the scientific defensibility of the information contained in each document. To reduce bias that could occur in determining these assessments, a standard procedure was developed to assign the level of relevance and data quality to each report.

The database entries contain standard bibliographic information including author, title, and publisher, It also contains a brief summary of the document, the document's library (catalog) number, and other information that is designed to help the user search for information specific to topics or locations.

Documents in the library will be available at the Center, probably in early January. The procedures for borrowing material (for self-serve copying) or requesting mailed copies are still being established, and their final nature will probably depend on the volume of interest that this library generates. The Center's web site will post the necessary information as soon as the procedures, and the materials, are ready. ❖

'Zero-Impact' Urban Development: Monitoring a Case Study

By Karen J. Comings, Graduate Research Assistant, Center for Urban Water Resources Management

INTRODUCTION

Urban development within a watershed typically takes place in a piecemeal fashion over the course of decades. Urban density increases as both developers and individual landowners build homes and infrastructure. Impacts to aquatic ecosystems within the basin become progressively more severe under these circumstances, because there is no coordination between builders or incentive to develop cohesive drainage mitigation.

This case study presents a unique opportunity to investigate the environmental impacts to a basin that is being developed under a single cohesive plan with unparalleled drainage mitigation. Ultimately, the development project should provide the opportunity to determine if 'zero impact' is a realistic goal, evaluate the effectiveness of current best management practices (BMPs) on a basin-wide scale, and improve methods of ecological monitoring. Because this is a long-term development project that is just beginning, this paper focuses on the monitoring challenges presented by such a project.

Two urban planned developments (UPDs), Blakely Ridge and Redmond Ridge, are being built side-by-side atop Novelty Hill near Redmond, Washington. These developments will have close to 3,500 homes as well as business parks, shopping centers, community parks, a school, and a golf course. Together these developments cover 848 hectares and span the headwater areas of seven separate watersheds. Prior to the start of construction, the area was prototypical of "undisturbed" lowland western Washington, lying on a gently rolling terrain underlain by glacial till and covered with mature second growth forest. Many large wetlands cover the area and serve as the headwaters to eight streams that flow off the property.

Both of the UPDs are being constructed under a "Master Drainage Plan," which stipulates that post-development hydrologic response must match the pre-development condition for most flow conditions. A comprehensive monitoring program is underway, executed jointly by the Center for Urban Water Resources Management at the University of Washington and King County, to determine if this goal is being met and, if not, what consequence this will have on the local stream channels.

MONITORING GOALS

A variety of consequences result from the urban-induced hydrologic changes in a watershed. In the case of the UPDs, local agencies expressed specific concerns regarding downstream erosion, flooding, water quality, decreased baseflow, and decreased groundwater (MDP 1996). Each of these potential consequences could have the further effect of degrading aquatic habitat. Furthermore, studies on the effects of urbanization have shown that changes to upland hydrology can have severe effects on channel erosion (Booth 1990), macroinvertebrate populations (Fore et al. 1996), large woody debris (Booth et al. 1997), pools (Horner et al. 1997), and amphibians. The monitoring program has been designed to identify any such problems at their onset so that steps can be taken to curtail further degradation. It has two basic goals: (1) to ensure that stormwater facilities are working as intended with regard to both treatment and hydrology, and (2) to identify and evaluate any significant changes to downstream natural resources affected by the UPDs.

A comprehensive monitoring plan has been created to address these goals. The first section of the monitoring plan is devoted to monitoring the stormwater facilities for both water quality treatment and hydrologic function. The remainder of the monitoring effort focuses on the condition of the downstream aquatic ecosystems, including streams, wetlands, and groundwater.

MONITORING CHALLENGES

Monitoring the ecological aspects of this or any other project presents numerous challenges because these systems are dynamic with inherently large variability, both spatially and temporally. Furthermore, relatively little data collection has been done in the headwaters of Puget Lowland streams, which have a character all their own. Most of the UPD streams begin at beaver dams that form the outlet of wetlands. Often the streams flow for several hundred meters over saturated soil before developing a granular channel bed. It is not uncommon for these mud-bottom streams to be vegetated with aquatic plants over some or all of the channel. During drier years several of these streams have proven to be ephemeral, with their beds changing from thick soft mud to dry hard-packed soil during the late summer. Many of the usual data-collection methods developed in the region can not be applied directly to these streams.

Exiting approaches and protocols have been altered to accommodate the needs of these small streams. The collection of macroinvertebrates, for example, typically takes place in September (Karr and Chu, 1999), a time when many of the UPD streams have gone dry. Samples are being collected earlier in the summer while water is still flowing. Such a change, however, means that B-IBI scores from the UPDs will not be comparable to other Puget Lowland streams, but they should provide baseline values needed to evaluate the streams over time. In addition, the mud bottom of many of the streams means that sampling sites had to be chosen far enough downstream for riffle-type habitat to have formed but not so far downstream that the site is beyond the influence of the UPD. Downstream alluvium channels are often measured with a 100-point pebble count to characterize the distribution of grains as well as other measures such as embeddedness. These types of measurements become meaningless when there are no large grains on the streambed, which occurs when such sediment-delivery process as soil creep occur more rapidly than fluvial sorting and transport. Here, 100-point pebble counts were taken where appropriate; farther upstream, the locations of mud-bottomed channels was noted. The utility of this characterization will be seen only after the opportunity for development-induced channel change has begun.

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Ecological data is notorious for high variability. Much of this variability is truly part of the population being measured. However, error is introduced in most data sets because of the difficulties with observer bias and repeatability (see also the 10:1 issue of this *Newsletter*). These difficulties can come from subjective differences between personnel, as well as inconsistencies in measurement methods from year to year. Measurements that are more subjective in nature can often be improved with the use of categorical data collection. For example, on the UPDs streams estimates of bank stability along each reach are categorized into excellent (> 80% stable), good (50-79% stable) and poor (< 50% stable), rather than attempting to pinpoint an exact percentage that would certainly be different for each observer. Some sensitivity is thus being sacrificed to achieve better replicability, a strategy that can be evaluated only after several years have passed.

It is important to determine if changes that appear in the data are from the development or from changes that occur naturally. This can be done by either comparing the data to a baseline data set or to a control data set. Baseline data for the UPDs was collected in the early 1990s and in most cases is comparable to data being collected now, even though some of the monitoring techniques have changed. Additional baseline data was collected during the year construction began as a comparison, because the initial baseline data spanned a five-year period prior to the start of construction. Little change was observed between the collection of data in 1992 and the latest baseline gathered in 1998, providing a basis to recognize and identify development-induced change is any does begin to occur.

CONCLUSION

While the concept of "zero-impact development" is desirable, it has yet to be proven as a possibility. The two UPD projects taking place on Novelty Hill represent the current best attempt at achieving this goal. Over the years of construction, the UPDs will be subject to intensive monitoring to determine if our current best management practices are adequate for protecting the natural aquatic resources within urban areas. As such, they represent a field "experiment" of unprecedented scope, complete with a monitoring program that should provide guidance for future urban stormwater mitigation strategies throughout the region.

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Sediment Budget of a Mixed-Use, Urbanizing Watershed

By Erin Nelson, Graduate Research Assistant, Center for Urban Water Resources Management

INTRODUCTION

The Issaquah Creek basin is an urbanizing watershed of 144 square km in western Washington, where sediment aggradation of the main channel and delivery of fine sediment into a large downstream lake (Lake Sammamish) have raised serious local and regional concerns. The basin has many water quality problems that may be associated with erosion occurring throughout the watershed. The water quality of Lake Sammamish is degrading with time, and fine sediment entering the lake from the watershed is a likely source of phosphorus during periods of lake anoxia. Additionally, there are flood-prone areas in the basin, particularly along the mainstem of Issaquah Creek in downtown Issaquah, that may be exacerbated by channel aggradation and subsequent reductions in flow conveyance. Another potential in-channel concern is the effect of fine sediment on spawning gravel for the salmon species that occupy Issaquah Creek. A sediment budget was constructed for this mixed-use, rapidly developing watershed to evaluate the relative effects of land-use practices, including urbanization, on watershed-scale sediment supply and delivery. It also can be used to identify the major sources of sediment, and thus guide the most effective remedial measures.

PREVIOUS STUDIES

Very few sediment budgets have been conducted in urban or urbanizing areas. The vast majority of sediment budgets in the literature are in forested or undeveloped drainage basins. Several studies have been conducted in forested Pacific Northwest drainage basins (Reid 1981, Madej 1982, Slaymaker 1993, Paulson 1997), where vegetated hillslopes are the dominant erosional features in the landscape. Of the few sediment studies conducted in urban areas, most have focused on one or more elements of sediment production, such as construction or channel-bank erosion resulting from urbanization (Wolman 1967, Wolman and Schick 1967, Trimble 1995, Trimble 1997). Other urban sediment studies have used sediment concentration measurements from catchment outlets to document the

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magnitude of upland sediment production from various land uses. While this information is useful to evaluate catchment-level changes, it is difficult to discern the significant sediment production processes from such aggregated data.

METHODS

Sediment production was evaluated for the different land uses in the basin, which include urban development, construction, forest/timber harvesting, and landfill and gravel quarry operations. GIS (Geographic Information System) data were used to determine land use categories and areas, and to evaluate basin characteristics that should influence erosion and sediment-delivery potential. Within each land-use category, the sediment production and delivery processes associated with each general land use were evaluated using a combination of methods described in the geomorphologic and engineering literature.

RESULTS

The current annual sediment production rate is estimated at 44 tonnes km^{-2} yr^{-1}, relative to a pre-development estimate of 33 tonnes km^{-2} yr^{-1} (1 tonne is 1000 kg, or about 10% more than a standard ton). The main sources of sediment in the basin are landslides (50%), channel-bank erosion (20%), and road surface erosion (15%) (Figure 1). Less significant sources of sediment included agriculture, construction, and landfill and gravel quarry operations. Although the Issaquah Creek basin is developing, forest lands still occupy over 70 percent of the basin area and produce the majority of sediment, where steep slopes contribute to a high landslide rate and efficient sediment delivery to the channel network. Urban land uses account for only 18 percent of the basin area and contribute very little sediment directly to the overall budget, because developed areas have only modest yields and a relatively small fraction of the basin is under construction at any given time.

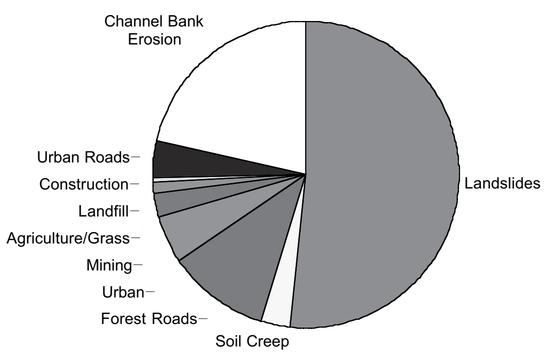

Figure 1. Relative Sediment Contributions from Different Land Uses and Geomorphic Processes

Sediment Size Fractions

Watershed managers have specific concerns related to the different size fractions of sediment delivered to the channel network, therefore, both fine and coarse sediment production processes were evaluated in this sediment budget. Increased coarse sediment supply can lead to channel aggradation, whereas abundant fine sediment usually leads to a reduction in water quality. Fine sediment accounted for approximately 60 percent of the total sediment production in the Issaquah Creek basin, primarily from landslides, gravel roads, and channel bank erosion (Figure 2). Landslides and channel bank erosion also contribute significant amounts of coarse sediment to the overall budget. Relative to the total sediment budget, urban land uses accounted for a disproportionately high percentage of fine sediment, indicating there are opportunities for better management of urban stormwater runoff.

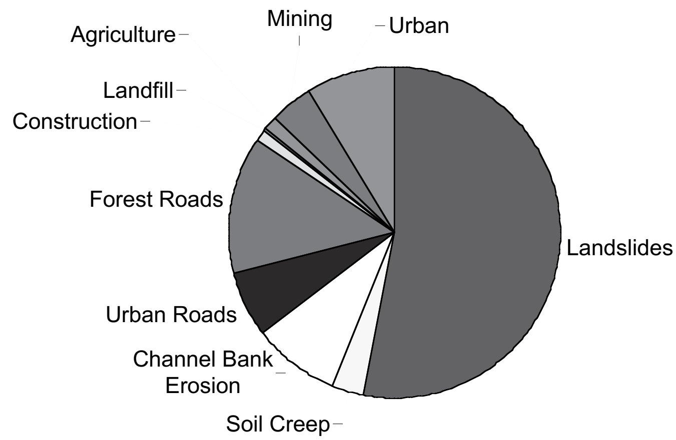

Figure 2. Relative percentages of fine sediment from different land uses/processes

BALANCING THE SEDIMENT BUDGET

A number of different approaches were taken to check estimates of upland sediment production in the basin, including an evaluation of depositional and erosional areas within the mainstem of Issaquah Creek, an evaluation of the growth of the Issaquah Creek delta into Lake Sammamish, and a comparison of these results with other studies.

Erosional and Depositional Areas in Issaquah Creek

Historical bridge survey records within the City of Issaquah indicate a net channel aggradation (ranging from 7 to 30 mm per year) in Issaquah Creek. The bridge survey data compared favorably to calculated channel aggradation rates (6 to 12 mm per year) based on estimates of upland sediment production and downstream routing and transport in the mainstem of Issaquah Creek.

Delta Growth

The average annual growth rate of the Issaquah Creek delta into Lake Sammamish was estimated from a review of historical aerial photographs (1944 to 1995) to compare estimated rates of fine sediment production from the watershed. The growth rate was estimated to be approximately 2,600 tonnes/year, which compares to an estimated fine sediment input of 3,800 tonnes/year. Recognizing that a significant, though indeterminant, fraction of the fine sediment would be carried in suspension far out into the lake, these results are fully consistent with the sediment-budget calculation.

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DISCUSSION

In general, the calculated sediment production rate of 44 tonnes km^{-2} yr^{-1} for the Issaquah Creek basin is higher than reported urban sediment yields, ranging from 10 to 35 tonnes km^{-2} yr^{-1} (City of Bellevue 1995), but much less than rates calculated by others for forested Pacific Northwest basins (Reid 1981, Madej 1982, Paulson 1997), which vary from 77 – 1800 tonnes km^{-2} yr^{-1}. It represents an increase of about a third in the pre-development sediment yield from the Issaquah Creek basin, calculated at 33 tonnes km^{-2} yr^{-1}, primarily a consequence of channel bank erosion. Bank erosion, resulting from channel enlargement due to increased discharges, account for 20% of the total basin sediment budget and is a direct consequence of urbanization.

More generally, channel bank erosion is probably the primary source of sediment in more urbanized watersheds. Trimble (1997) found channel bank erosion to be the primary source of sediment yield (67%) in San Diego Creek basin, a 50%-urbanized watershed in southern California. These results indicate an often-overlooked reason to mitigate impacts from stormwater runoff as rural areas are developed. Unlike more visible sources of sediment (such as construction runoff), channel enlargement is a process that can occur without much notice from human inhabitants until property is lost or structures are threatened.

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This thesis for this article is available from the Center as publication K23. ❖

Regional, Synchronous Field Determination of Summertime Stream Temperatures in Western Washington

By Derek B. Booth, Center for Urban Water Resources Management

Cold-water fisheries can be strongly affected by elevated summertime stream temperatures. The determinants of stream temperature are relatively well understood in the abstract, but their quantification in any given watershed is confounded by the vagaries of groundwater and surface-water inflows and the complex interplay of stream orientation and sun angle, canopy cover, and air temperature. Individual temperature measurements can give insight into the specific conditions for a particular stream, but they do not provide the context to evaluate unusual natural or human-induced temperature conditions at any given site.

For the second year running, the Center for Urban Water Resources Management, in cooperation with the Center for Streamside Studies and local stormwater agencies, tribes, and citizen groups, coordinated a regional, one-day intensive stream-temperature monitoring survey. This year we took two hours on Wednesday, August 4th in the hottest part of the day (3-5 PM) to make our measurements. Our intention was to characterize the range, distribution, and determinants of summertime high temperatures in fish-bearing (and tributary to fish-bearing) lowland stream systems in the Puget Sound lowlands. Sites were arrayed to provide system-wide coverage, with watershed areas ranging from 100 km^2 on down to the limits of perennial flow. Reflecting our interest in quantifying human influences, we targeted watersheds with primarily urban and suburban land uses but included some rural and forested basins as controls.

The motivation for this study follows the broader goals of our larger, three-year investigation of urban stream degradation and rehabilitation: What determines whether biological conditions in streams are good or bad? Which of those determinants can be affected by human development? Which are particularly likely to be degraded significantly in urbanizing areas? Our approach in this larger study has been to investigate potential causal mechanisms to determine if they are significant, and also to look for correlations between the spatial variability in an particular physical condition, such as stream temperature, and the observed variability in biological conditions. A broad set of data is still being analyzed for this investigation; here, some preliminary results from the temperature survey can be offered.

Over 100 individuals collected over 700 temperature measurements across the south-central Puget Lowland in this two-hour period (Figure 1). Participants came from the cities of Bellevue, Renton, and Seattle; King County, Kitsap County, Pierce County, and Snohomish County; Washington State Department of Fish and Wildlife; the Tulalip, Stillaguamish,

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and Muckelshoot tribes; the Adopt-a-Stream Foundation and Thornton Creek Alliance; and the Pierce County Conservation District. The Center drew up field forms and established protocols for the temperature measurements to ensure consistency in the data. We also defined routes for the individual volunteers, using the following criteria:

- Can be accomplished in 2 hours, which resulted in anywhere between 4 to 20 sites, depending on distances and individual enthusiasm
- All sites readily accessible (road crossing, public park, etc.)
- Within jurisdiction (as needed, for some agency staff)
- Stays on a single channel system (ideally)
- Includes replication of one early site with a revisit to the same location late in the 2-hour period
- Duplicates at least one site from another route, preferably at a significantly different time in the two-hour period.

The air temperature that day (27 °C) was significantly hotter than the month's average (23 °C) and only slightly cooler than the maximum for the month (28 °C). Our results are therefore representative of the near- (but not absolute) maximum conditions (Figure 2). Measured water temperatures in 1999 ranged from 9 to 27.5 °C (1998's measured range was 9 to 25 ∞C); the average temperature across all stations was 16.5 °C in 1999 (and 15 °C in 1998).

A major focus of this year's investigation was to determine the reliability and replicability of these measurement techniques, and to determine if the data so collected could discriminate genuine temperature trends from imprecision in the measurements themselves. Over 60 replicate measurements were made, by both the same individual (at different times in the 2-hour period) and by different individuals visiting the same spot (also at different times, generally). The paired measurements are graphed in Figure 3, which indicate that nearly all measurements are within about 0.5 degrees of each other, regardless of whether the same or different people were reporting the values. Although not negligible, this difference is far less than the range of temperatures reported, and it suggests the magnitude of differences that are required for "significance." Investigators this year recorded the time at which their measurements were made; there is no trend to the temperature measurements across the two-hour period.

Analysis of the controls on stream temperature are only just beginning; a full report is anticipated later this winter. In general, "rural" streams are only slightly cooler, as a group, than suburban and urban streams. The presence or absence of a riparian canopy, of which both conditions are found in both urban and agricultural settings, exerts a much clearer influence—average differences of about 2 °C can be recognized, and the incidences of extreme high temperatures virtually *require* a loss of shading (Figure 4). Anticipated, but not yet explored, is the control of geologic conditions, because areas with deep permeable deposits are likely to supply a much higher percentage of deep (and cool) groundwater to stream baseflow than those draining uplands with shallow soils underlain by glacial till.

The raw data for this study are posted on the Center's web site (under "RESEARCH"). Participants and other interested parties alike are welcome to inspect the data, to explore rela-

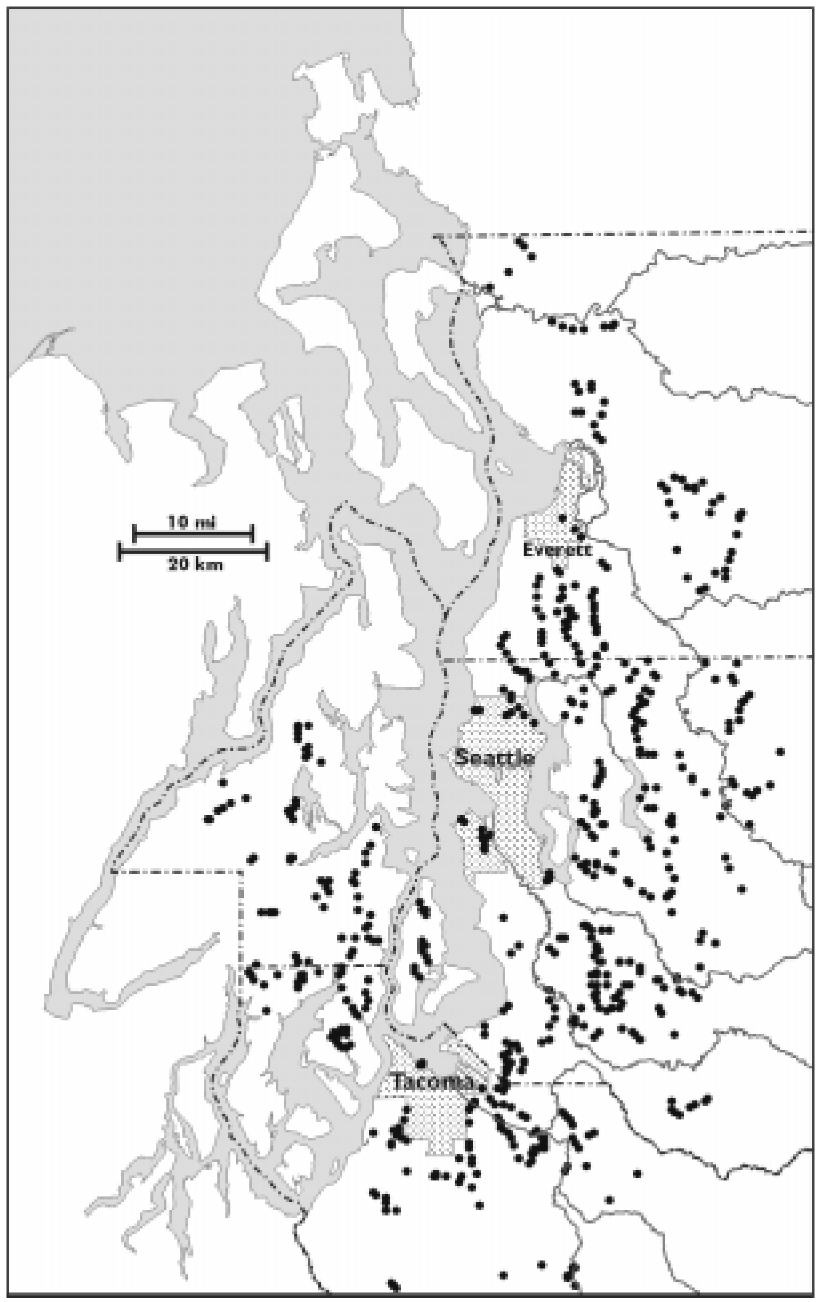

Figure 1. Location of temperature sampling sites.

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PROFESSIONAL ENGINEERING PRACTICE LIAISON (PEPL) Program

The PEPL (PROFESSIONAL ENGINEERING PRACTICE LIAISON) Program, in cooperation with the Center for Urban Water Resources Management, offers a continuing education program in urban water resources management.

As part of the benefits extended to supporters of the Center for Urban Water Resources Management, member organizations are eligible for a discount if sending groups of three or more to the same course. For further information, please contact:

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April 12 - 14, 2000
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April 26 - 27, 2000
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May 11 and 12, 2000
New Technologies and Concepts in Stormwater Treatment

<http://www.engr.washington.edu/epp/PEPL/peplcal.html>

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tionships with other parameters, or to use the temperature data on particular systems as part of a watershed characterization. As additional results are developed, they will be posted there as well. We are also embarking on a new stream-temperature project in 2000 for the next three years, funded by the U.S. Environmental Protection Agency, to explore the utility of temperature measurements made at different scales (including satellite platforms as well as ground-based measurements). A description of that project will appear in the next issue of the *Newsletter*. ❖

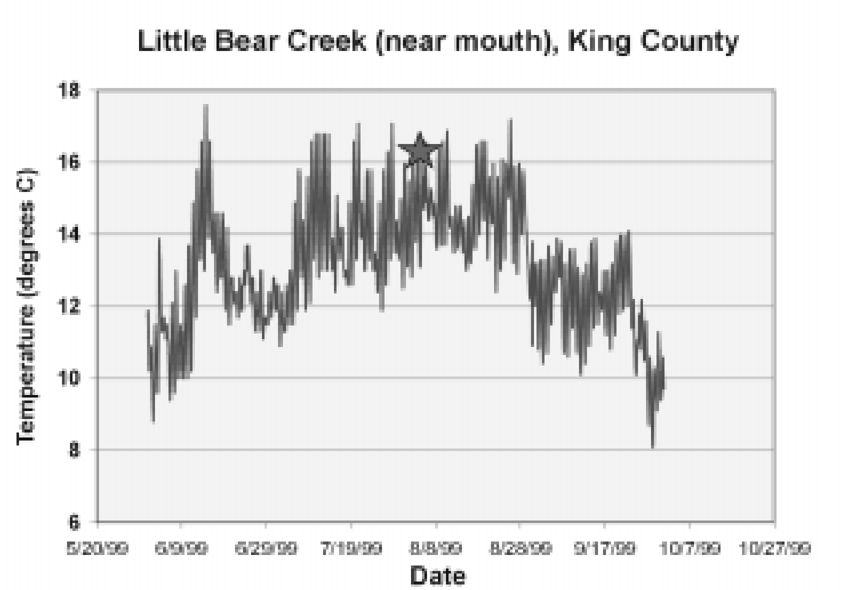

Figure 2

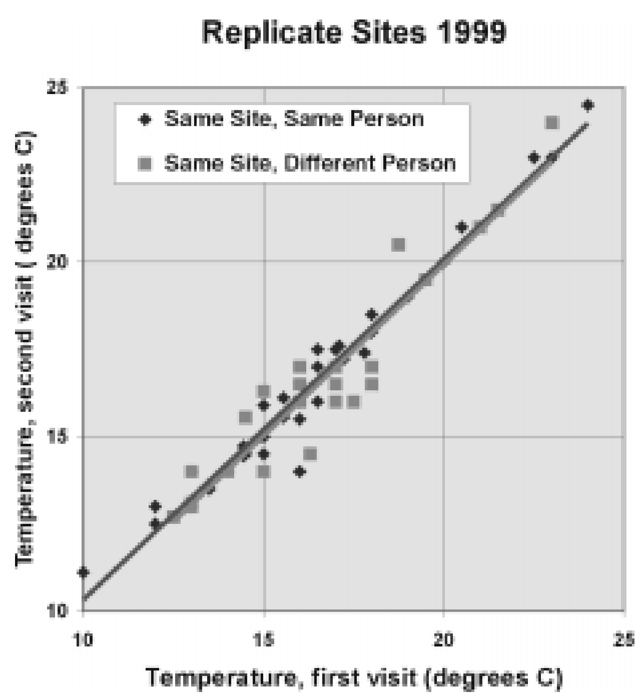

Figure 3

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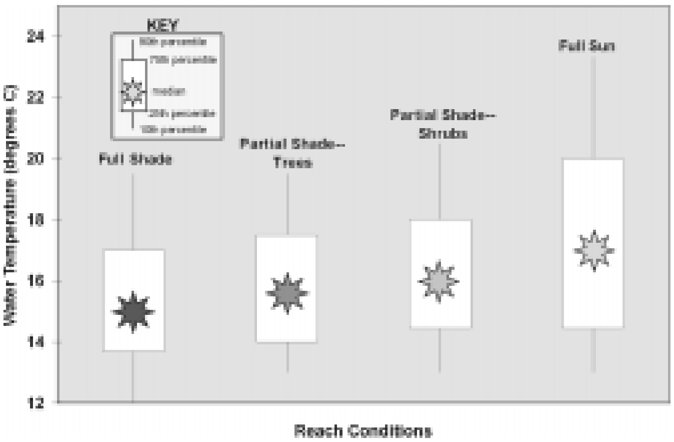

Figure 4

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

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

SURVEY RATIONALE AND COVERAGE

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 have 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. Richard Horner has been the lead faculty investigator on this effort, with ongoing participation by graduate research assistants Shanti Colwell and Dalius Gilvydis. The goal of this investigation is to develop strategies for improving runoff treatment and reducing downstream sediment loading from existing ditches, while retaining their hydraulic function of conveying roadway runoff. The principal focus has been 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 we 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

Continued on page 10

SURVEY (from page 9)

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 ditch bed transects had 95-100 percent vegetation cover (and 25 percent with 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.

Continuation of Existing Practices:

- In future roadside ditch site selection and design continue to avoid heavy shading and steep slopes. Continue to use U-shaped ditch profiles.
- Make side slopes no steeper than 3:1 (horizontal:vertical), if possible, and never steeper than 2:1.
- 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).
- Remove large woody growth before it has an opportunity to damage or take space from finer growth that makes a better treatment medium.
- Continue to avoid herbicide applications that damage ditch vegetation.

Recommended New Practices:

- Design point inlets of new ditches to distribute flow across the full width using a flow spreader (see biofiltration guidance in the King County Surface Water Design Manual for specifics).
- Retrofit existing ditches with evidence of channelized, incising flow with energy dissipaters, check dams, and/or flow spreaders.
- If a poor growth medium, especially rocky soil, is present, over-excavate the poor medium and replace with a more favorable one.
- Attempt to avoid standing water by siting ditches where high water table is not likely, sloping at least 2-3 percent if possible, and careful 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.
- Specify and plant a mix of grasses and other fine, close-growing herbaceous plants, including wet-tolerant and drought-tolerant species.
- There may be aesthetic and other operational reasons for mowing. Environmentally, judge the need for mowing with respect to nutrient control objectives. If the ditch drains to a water body sensitive to nutrient income, mow it late in the growing season (and earlier if desired). Whenever mowing is done for any reason, remove the cuttings promptly and thoroughly.

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. ❖

Regionalization for Water Supply Systems in the Central Puget Sound Region

By Amy R. Groome, Graduate Research Assistant, Department of Civil and Environmental Engineering

The Everett Public Works (Everett), Seattle Public Utilities (Seattle), and Tacoma Public Utilities (Tacoma) are the three public agencies that supply water to over 1.5 million people in the Central Puget Sound Region. These agencies face common challenges, including increasing instream flow requirements, developing new water supply sources, and maintaining existing but presently unused water rights. One alternative to costly new water supply development is *regionalization*: connecting the supply systems, promoting the transfer of water rights, and making more efficient use of existing sources. In addition, regionalization provides supply redundancy, lessening the vulnerability of each system. This is especially important for the Everett system, which currently relies on just one supply source.

A regional water supply model (CRYSTAL) was developed to evaluate the benefits from interconnecting the three utilities and managing the supply system from a regional perspective. This thesis focuses on the interconnection between Everett Public Works and Seattle Public Utilities. The results show that there is sufficient supply storage in the Everett system to supply the region through 2040 demand projections. An Everett– Seattle intertie (ESI) improves long-term supply availability, provides needed supply redundancy for the Everett system, and can enhance instream flows in the Cedar and South Fork Tolt Rivers. When the intertie is operated only during low-flow years the same water supply benefits are derived, but the enhancement of instream flows is lessened.

The estimated costs of different ESI scenarios are competitive with other regional supply options. Although an additional foregone cost is incurred from decreased hydropower production in the Sultan River, it is small relative to the overall projected costs. In summary, a potential ESI could provide solutions to current regional water supply problems and merits further investigation. ❖

Ultra-Urban Stormwater Management Review

The Center has recently begun a project with Seattle Public Utilities to help evaluate the effectiveness of its stormwater management Capital Improvement Projects (CIP's). Because the City of Seattle is so fully developed, the typical strategies for stormwater management that are triggered by new development, and that presume the availability of adjacent land for construction of capital facilities such as detention ponds or biofiltration swales, are typically infeasible. The City has embarked upon a project to evaluate a suite of "ultra-urban" approaches that hold promise for improving the water quality of stormwater runoff, that promote infiltration of surface discharges, and that delay the release of runoff into the adjacent streams. Such measures have long been recognized as necessary components of a regional, urban, stormwater management strategy, but there are very few examples of such measures and almost none with sufficient monitoring or evaluation to determine their success and broader applicability. This project is an effort to rectify that shortcoming on behalf of not only the City of Seattle but also the other largely or fully developed parts of the region. The Center faculty and student working on this project are Richard Horner, Stephen Burges, Derek Booth, and Adrienne Miller; Darla Elswick and Tracy Chollak are project leads for the City.

The Center has been asked to help develop a long-term, systematic approach to ultra-urban stormwater management in Seattle stream catchments. In particular, we are looking to identify the types of projects with potential to improve ultra-urban stormwater management in the city's watersheds, via consultation, review of the existing literature, and our own experience. We then need to adopt a simple but formal screening method that will evaluate any given project's applicability, its ecological benefits, and its cost-effectiveness. We have already prepared an experimental design and a monitoring plan for testing the initial projects, which were previously chosen opportunities to investigate the effectiveness of different techniques. These projects represent potential management techniques that could be implemented in highly urbanized areas on a more widespread basis, and include a redesign of a residential street in the Viewlands neighborhood of the Pipers Creek watershed, evaluation of the hydrologic benefits of expanding the area associated with street-tree plantings, and a rooftop garden demonstration at the new Thornton Creek Interpretive Center near Meadowbrook Pond.

We have been particularly active this fall in installing flow and meteorological data stations at several of these sites. These include not only the standard flow and precipitation gauges, but also evaporation and radiation measurements that should allow us to develop a full characterization of the hydrologic cycle at these sites—rainfall, evaporation, and runoff. We lack only a direct measurement of infiltration and groundwater recharge, but the quality of the data we hope to collect should permit the estimation of this last parameter as well with good accuracy. We expect to produce a report at the end of this year that evaluates the first-year construction and monitoring effort, characterizes a suite of ultra-urban strategies that hold good promise for success, and recommends an approach for the next steps in this project. ❖

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The Washington Water RESOURCE

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Rates of Channel Erosion in Small Urban Streams

By Derek Booth and Patricia Henshaw, Center for Urban Water Resources Management

This study was initiated in 1986 to provide data on the rates of urban-induced channel change, focused on a part of western Washington state where (and beginning at a time when) the rate of new urban development was accelerating at historically unprecedented rates. It also began when the social and political desire to alleviate the worst environmental consequences of that development far exceeded the concrete knowledge necessary to achieve that goal.

Starting in 1986, 35 stations along an equal number of independent streams were established to monitor long-term channel changes in urbanizing watersheds. The purpose of this effort was four-fold:

- To document erosion and deposition rates in a variety of physiographic settings;
- To test the hypothesis that urban development consistently increases the rate of channel change, and that higher levels of urban development are correlated with faster rates of channel change;
- To test the hypothesis that certain geologic and/or topographic settings are particularly susceptible to urban-induced channel changes; and
- To allow prediction of the most susceptible sites before development has occurred, and thus before degradation has begun.

Price = $5.00 (Publication K22)

Sediment Budget of a Mixed-Use Urbanizing Watershed

By Erin Nelson, Center for Urban Water Resources Management (see associated article on page 4)

Price = $27.00 (Publication K23)

Restabilization of Stream Channels in Urban Watersheds

By Patricia C. Henshaw, Center for Urban Water Resources Management

The transition of a watershed from the natural, forested state to a predominantly urban condition encompasses removal of vegetation and canopy, compaction of soils, creation of impervious surfaces, and alteration of natural drainage networks. These actions result in increased surface runoff and changes to sediment budgets. These changes, in turn, induce a geomorphic response, commonly resulting in enlarged, unstable channels. However, any subsequent ability of the channel to restabilize over time is not well understood. The purpose of this study was to determine whether channels in urban watersheds are capable of restabilizing over a period of years to decades. Based on a variety of field and historical data from several streams draining urban and urbanizing watersheds in the Puget Sound lowlands (PSL) of western Washington, this study investigates the relationships between channel stability and watershed urbanization, and between stability and other factors that may also affect the timing or extent of geomorphic response.

The results indicate:

- Restabilization of urban stream channels in the PSL can, and commonly does, occur even in highly urbanized watersheds. However, the degree of stability is not well predicted by either the magnitude or the rate of development.
- Most, but not all, PSL streams are likely to restabilize naturally within 10 to 20 years of constant land cover in the watershed, and possibly even more rapidly.
- The likelihood that a channel will restabilize depends primarily on hydrologic and geomorphic characteristics of the channel and its watershed, not the magnitude or rate of development. The hydrologic regime and geologic setting appear to be important controlling factors; extent of grade control and the extent and condition of the riparian corridor may also play noteworthy, but less influential, roles.

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