FORWARD

In the following pages, speakers at the Salmon In the City Conference inform us that urbanization is damaging fish habitat in small lowland streams in the Puget Sound Basin and British Columbia, and they describe the causes and extent of the damage. On the poor soils that predominate in the area, the damage begins with the first few percent of impervious surface in the basin and, for most such streams, reaches massive proportions when it becomes 20% to 30% impervious. For these urbanizing watersheds, the very high stream flows that accompany traditional development are more critical than the water quality impacts of such development, for in the course of forest conversion increasing flows erode the channel and ruin habitat long before the impacts of water quality degradation are felt.

Speakers point out that good habitat is characterized by a forested watershed that provides fish and other aquatic life with year round, cool, well modulated stream flows, shelter, and food. If the forest is converted to urban uses (in the traditional manner), speakers offer no engineering solutions to replace its functions. However a few speakers suggest that where development and conversion of forests will take place, there may be non-traditional ways to greatly mitigate such new land use and prevent major impacts to streams. These include design and construction methods that retain most of the forest and reduce “effective” impervious surface area to near zero. Because there are no examples where such a condition has been intentionally achieved, a few speakers advocate a demonstration project which, if it has the expected effect, could be used as a model for revision of development standards.

Speakers offer little encouragement for the possibility of restoring damaged urban streams without restoration of their watersheds. A restored watershed, capable of sustaining runs of wild anadromous and native fish, will have 60% to 70% of its area reclaimed as forest, stormwater outfalls removed, most stream crossings closed, large natural buffers reclaimed, and impervious areas reduced to effectively zero. In the short term, such restoration of any thoroughly degraded urban stream is probably not possible because of the staggering costs involved and traditional funding shortages for such activities. Further, speakers warn us that urban stream restoration may not even be wise, in the short term, if such restoration meant that the relatively minor financial resources required to preserve existing, quality habitat were diverted to the prohibitively expensive restoration of even the smallest of urban watersheds.

The data imply that urban watershed restoration, where we choose to do it, is practical only in the long term. Over long periods of time, restoration of urban watersheds (much of which will redevelop with or without a restoration strategy) might be made to pay for itself. The mechanisms for such results are dramatic changes in re-development policy and a redefinition of the term “long range” planning.

The quest to restore urban watersheds brings us into truly uncharted waters. We are asked, like those who built cathedrals in the middle ages, to begin an activity that may show us little benefit in our lifetimes and that only our descendants can finish. Speakers urge that we ask ourselves if we have the vision and the will for such a commitment.

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INTRODUCTION

The *Salmon in the City (Can Habitat in the Path of Development be Saved)* conference was presented by the American Public Works Association (APWA), Stormwater Managers Committee joined by cosponsors. This was the third conference on the theme of impacts of urbanization. The first conference in the series was called *Hydrology and Erosion Aspects of Timberland - Urban Conversions*, November 15, 1988, presented by The American Water Resources Association and the University of Washington. The second conference was called *Salmon in the City: Effects of Urbanization on Fish Habitat*, March 11, 1992, also sponsored by APWA and others. With the passage of years, attendants at these precursory events still claim that they were the best conferences that they had attended. They have set the stage for this event, which was held on May 20-21, 1998, in Mount Vernon, Washington.

With this conference the scientists and engineers who have been studying urbanization impacts for nearly two decades reach out to the broader community. It is our hope that we can assist the community in responding to the threat of fish extinction owing to urbanization.

Regrettably some conference speakers' schedules did not allow them to submit abstracts for inclusion in this document. As if notes were omitted in a symphony, the theme does not flow as mellifluently to its conclusion. But much as those papers are missed, the conclusions drawn from those that follow are unambiguous and inescapable. We must preserve, untouched, forested watersheds that are still functional where we can. Where development will continue, we must preserve riparian zones and abandon traditional development procedures. Speakers have provided us with a paucity of options, but perhaps that is good. Will that not make it easy to decide what to do?

ADDITIONAL COPIES

Additional copies of abstracts are available for a nominal fee. Call Washington State University, 253-445-4575 or Tom Holz, Conference Chair, SCA Engineering, 360-493-6002.

TAKING STOCK: ANADROMOUS SALMONIDS AND THEIR HABITATS IN THE PUGET SOUND BASIN

By Kurt L. Fresh

It is well known that the abundances of many naturally spawning populations of salmon and steelhead in the Pacific Northwest have recently declined to critically low levels. Changes in abundance of anadromous salmonid populations are a result of the cumulative effects of many factors including over harvest, changes in freshwater habitats, changes in estuarine habitats, ocean conditions, and introductions of exotic species. In most cases, isolating the effects of any one factor is difficult if not impossible. However, because salmon require high quality freshwater spawning, rearing, and migratory habitats, it is clear that loss and degradation of these habitats is a major reason for declines in abundance of many anadromous populations.

Urban lands make up about 2% of the land base in Washington. However, they exert a disproportionate influence on anadromous salmonid populations because they encompass prime spawning, rearing, and migratory habitats. Most of the urbanizing land in Washington is located in the Puget Sound region. For purposes of this talk, I define the area most at risk to effects of human development as the east and southern portions of Puget Sound (Whatcom, Skagit, Snohomish, King, Pierce, Thurston and Kitsap counties) and a portion of Mason county. Although this represents about 17% of the area of Washington, it contains 64 % of the human population of the state (1996 data), primarily in the lowland portions of Pierce, King and Snohomish counties.

The overall objective of this talk is to examine the condition of anadromous salmonids and their stream habitats in this region of Puget Sound. My intent is to try and develop a report card on the condition of salmon and their habitats today in this region especially in the region most vulnerable to human population growth. The species considered include coho salmon, chum salmon, chinook salmon, pink salmon, sockeye salmon, and rainbow (steelhead) trout.

The data used in this analysis came from a variety of published and unpublished sources including WDFW salmon and steelhead records, plans for individual cities, drainage districts and counties, basin and watershed management plans, and unpublished GIS (Geographic Information Systems) types of data such as the Pacific Northwest River Reach data. Where possible, an effort was made to use published data sources. As an index of the condition of anadromous salmonids, I primarily used escapement (number of fish returning to spawn) data for return years 1985-1995. These escapement estimates are generated using a variety of methods that vary with species and with area. The period 1985-95 was selected because data obtained during this period is more complete and of higher quality than earlier information. The data that I used on physical characteristics of the landscape included such information as percent developed land, basin area, and stream miles; much of this information was generated between 1990 and 1995.

Available information varied considerably in quantity and quality. For example, impervious surface estimates were only available in some systems. In general, the data tended to be more consistently available and comparable at larger scales (such as at basin scales) and became less consistent as the scale was reduced to individual subbasins. For many streams, there was relatively little known about either adult or juvenile salmon usage. The level of knowledge varied with species and area. One especially striking illustration of example of this is that escapement surveys are not conducted in most streams in urban areas; in the Lake Washington system, for example, < 3% of the stream miles are surveyed for coho salmon spawners.

Within the study area, the most numerous species (based upon escapement estimates) were pink salmon, chum salmon, and coho salmon. The Skagit River Watershed had the largest escapement of anadromous salmonids, primarily because of the large numbers of pink salmon that use the system. Using phenotypic and genetic characteristics, each species found in the Puget Sound basin has been divided into populations or stocks which represent distinct groups of fish that are more or less reproductively isolated and differ in their spatial and temporal use of habitats. Typically, stocks are aggregates of fish that use a number of discrete basins and subbasins. Within the study area, I identified a total of 139 stocks out of a statewide total of 435 (based upon a 1993 published inventory of salmon and steelhead in the state), including 26 chinook stocks, 38 chum, 24 coho, 9 pink, 4 sockeye and 38 steelhead. Of the stocks that utilize freshwater habitats in the study area, about 23% have been classified as in critical or depressed condition compared to13% statewide. The highest proportion of any species classified as depressed or critical was sockeye (100%) and chinook salmon (40%). None of the pink stocks and only one chum stock was classified as depressed or critical.

An evaluation of the risk of urbanization can be made based upon the general types of functions the streams have for salmon and steelhead. I considered three different functions: upstream and downstream migration, spawning/incubation, and rearing. Most salmon and steelhead in the Puget Sound region are at risk to urban effects only during upstream and downstream migrations as they pass through urban areas on their way to and from headwater streams to spawn. This is especially true of pink salmon which spawn primarily in the mainstem areas of several of the larger river systems (e.g., the Skagit and Snohomish river systems) and do not rear in freshwater. Coho and steelhead are especially vulnerable to urbanization because they can spawn, rear, and migrate in urban environments. Moreover, they rear for the longest period in freshwater.

The overall goal of this work was to develop a report card of the condition of salmon and their habitats in the Puget Sound lowlands. I was only partially successful in accomplishing this goal because the type of information needed to develop a report card often did not exist, was not easily accessible, was inconsistent (not collected or reported in the same fashion), outdated, or was only available at scales that did not seem particularly relevant to local land use planning and actions. Thus, I believe that there is a strong need for state, tribal, and local governments to work cooperatively to develop the information needed for a comprehensive report card that can be regularly updated.

The Puget Sound landscape inhabited by salmon and steelhead will change since it is the focus of most human population growth in the state. To understand the implications of these changes to salmon and steelhead populations requires an assessment of conditions now and in the future. Without this information, it will be difficult to assess how well we are managing growth in the region and the results of actions we may take to protect and restore salmon and steelhead populations.

SALMON IN THE CITY – TRENDS IN GROWTH MANAGEMENT

By Les Eldridge

It is impossible to address the theme of the impacts of urbanization upon salmon without speaking of rural and resource areas. You cannot talk of the cities unless you talk of the counties. Their relationship is inexorably intertwined. What happens in one area has a direct and noticeable effect on the other. This is particularly true when addressing what the Growth Management Act (GMA, Act) refers to as critical areas that include fish and wildlife habitat.

My perspective on trends in growth management is different from the practitioners at the growth management section of the Department of Community, Trade, and Economic Development (CTED). They can see the big picture, how well or how poorly jurisdictions are doing in relationship to the GMA and the CTED guidelines that help to implement it. All of the GMA-responsible jurisdictions in the State come through CTED with their draft plans and their requests for technical assistance.

Our perspective is different. The Western Washington Growth Management Hearings Board has a 14-county jurisdiction. Eleven of those are required to plan. We glimpse the progress or lack thereof in a jurisdiction's efforts to meet the requirements and goals of the GMA only when we receive a petition for review of a comprehensive plan (CP), an element thereof, or the implementing regulations for that plan. Or, we review when the plan or ordinance is not adopted on time and we receive a request to declare noncompliance owing to a failure to act on part of the jurisdiction. Ours is a window with the shade down. From time to time there is a rap on the window. We raise the shade and we examine what is before us. We render a judgement and we pull the shade down until the next knock. Nonetheless, with more than 215 petitions filed in our 14 counties we have raised the shade often enough to form opinions of the direction of growth management in the State of Washington.

The debate over restoration of salmon habitat has raised many questions. Can we remove barriers and improve habitat in urban areas sufficient to allow increased numbers of salmon to reach spawning grounds in the rural areas? This question leads to another; If urban barriers and habitat are improved and the salmon do reach the rural areas in increasing numbers, what is the quality of habitat there, and will the extent of that habitat there be adequate for restoration?

The GMA itself is a document fraught with conflicting sections and ambiguities. Hooray! Says one part of me. Otherwise I would not have a job, at least this job! Section 172 of the Act dealing with best available science is typical of the ambiguous section with inherent unanswered questions. What is best available science? What does it mean for jurisdictions to include it in the development of plans and ordinances? What bearing would listings under the endangered species act have on the application of this section?

I see two paths that are open to us in the general sense. We may listen to those who say that the GMA is too prescriptive, that it takes away too much of local government authority and impinges too much private property rights. We then may continue to use and consume resources in rural lands at 1980 rates until, as we reach 8 million people in the second decade of the next century, we run out of rural land and resources. Then we can look back and try to reverse the irreversible.

Or, we can continue implementation of the GMA and its amendment and improvement. We can apply the concurrency requirement of the Act, which require jurisdictions to demonstrate how infrastructure improvements will be paid for before they are committed to. We can apply for what I refer to as the "new concurrency," water availability and the demands of the endangered species act, to the accommodation of new growth. We can continue to improve our design and construction of urban areas to be more attractive and livable. In doing so, we will conserve for our grandchildren rural lands which are rural and natural resources which are protected and preserved and sustained. My wife's large family had a saying uttered at the crowded dinner table during the post-depression years: "Take a little from a little, leave a little there." We should consider that admonition as we choose the trend line we wish to follow.

NEEDS OF SALMON IN THE CITY: HABITAT IN THE URBAN LANDSCAPE

By: Robert R. Fuerstenberg

INTRODUCTION

Aquatic habitats critical to salmonids are the outcome of physical, chemical and biological processes acting across various scales of space and time. The environmental conditions that result from these processes provide the habitat requirements for a variety of species and life history stages of salmonids and other stream dwellers. Whether in pristine watersheds or in those most heavily urbanized, the basic requirements for survival of salmonids are the same. Salmonids are temperate and subarctic (and rarely, arctic) zone fishes, well adapted to the cold, clear, waters of Pacific Northwest rivers and streams.

HABITAT

Salmon—at least the anadromous ones—must live in and migrate through three quite distinct aquatic environments: freshwater, estuarine and marine. Within those large environments, however, salmon are apt to be found in particular local environments at particular times during their life history. These local environments possess the combinations of physical, chemical and biological conditions to which salmon have become adapted over the many thousands of years they have occupied the Pacific Northwest. Thus, habitat can be thought of as the set of environmental conditions, variable in space and time, that salmon require for survival; more simply, as those places where salmon are "apt to be found". When considering habitat requirements, it is necessary to keep in mind some important characteristics of salmonid ecosystems (Spence et al, 1996):

? Watersheds and streams differ in a variety of physical, chemical and biological characteristics.
? Salmonid populations are locally adapted to these conditions and their natural fluctuations.
? Specific habitat requirements differ among species and life history stages, and change with the season.
? Aquatic ecosystems are dynamic, undergoing periodic cycles of disturbance and recovery.

Everest et al (1985) noted that while it is certainly the case that each species of salmonid differs in its specific habitat requirements, all species share some basic habitat needs. In rivers, all salmonids require cool, flowing water free of pollutants and high in dissolved oxygen; gravel substrates low in fine sediment for reproduction; unimpeded access to and from spawning and rearing areas; sufficient refuge and escape cover; and sufficient invertebrate organisms for food. Bjornn and Reiser (1991) provide a detailed review of freshwater habitat requirements from a variety of field observations and laboratory studies. Pearcy (1992), in his review of ocean ecology of salmonids, discusses estuarine habitat requirements that are functionally similar to those in freshwater: areas of cold, well-oxygenated water; refuge for resting and escape from predators; sufficient food resources; and, unique to estuaries, mixing zones of reduced salinity necessary for making the physiological transition from fresh to salt waters. In the ocean environment, most of the same characteristics are necessary for salmon survival as well, and the various species may migrate great distances to reach areas of the Pacific where these conditions are found. Regardless of the environment, all habitats have physical, chemical and biological components that influence the survival of the various species and life history stages of salmon. Table 1 outlines some of the important features of freshwater habitat for salmonids. Within this basic framework are five classes of features that determine the suitability of aquatic habitats for salmonids.

Table 1. Important Components of Freshwater Habitat for Salmonids

Physical	**Flow Regime**
	-Depth, velocity, seasonality
	Habitat Structure
	-Substrate material, size and distribution
	-Channel Morphology
	-Channel slope, width, depth
	-Bedforms: pools, riffles
	-Large Woody Debris
	-Cover
	-Escape, feeding, resting
	-Riparian structure
	-Stand composition, age
	-Temperature
Chemical	**Water Quality**
-Dissolved Oxygen	
-Anions and Cations (pH)	
-Dissolved Nutrients	
	-Pollutants
-Turbidity	
Biological	**Interactions among species and life histories**
	-Competition
	-Predation
	-Biological modification
	-Redd building
	Energy Supply
	-Riparian inputs
	-Carcass loading
	-Instream inputs/macroinvertebrates

This generally simple view of habitat belies the true nature of the complex and dynamic nature of ecosystems. We tend to describe habitat based on that which is most visible and observable; and often impose on it a stability and uniformity that does not, in fact, exist. We must keep in mind that habitat is the product of the interactions among the features in Table 1 and is therefore far more complex than this simple assortment suggests. These features vary over a season, some over decades, and others over centuries. Flow, for example, falls to its lowest in the late summer when streamflow may be intermittent or absent all together in small streams. Runoff during late winter, however, may crest the streambanks and be 20, 30 or 40 times the summer flow. Even at this short time scale, the habitat structure of the system is very different to the species and life stages dwelling there. Habitat structure also varies from place to place across the river landscape. As one travels from headwaters to estuary, flow increases, sediment distribution and bedform change, flood-tolerant species come to dominate the riparian zone, and temperature patterns are altered. Large woody debris, so critical to sediment storage and pool formation in upper and mid-river reaches, tends to function more as refuge or as substrate in the lower reaches, often partially buried in the fine sediments of the river bottom or encrusted with barnacles on estuarine mudflats.

Habitat is the outcome of various processes, each with its own characteristic rates, magnitudes, spatial and temporal scale (Spence et al 1996), and can be usefully characterized as the relationship among process, structure and function within ecosystems (Figure 1). At large spatial and long temporal scales, the dominant processes that shaped PNW landscapes were tectonic and glacial. These processes established the landscape framework upon which further processes occur. Over periods of decades to centuries, large floods, mass wasting and fires have been the dominant processes shaping riverine ecosystems. These disturbances have caused abrupt changes in habitat conditions: large floods reconfigure the channel, often causing channel migration and abandonment, redistribution of bars and pools, and thus the destruction of existing habitats and the formation of new ones. Changes in the structure may persist for decades or centuries, affecting the relative suitability of these habitats for various salmonid species. This natural disturbance and recovery regime, however, has directed the evolution of life history characteristics and strategies for salmonids.

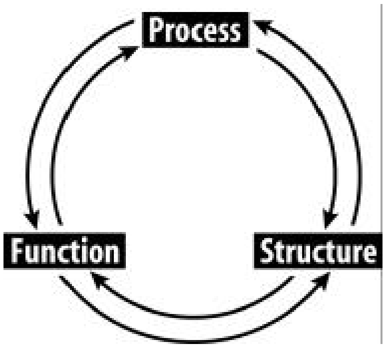

Figure 1.

At the watershed scale, the major physical processes that affect the attributes of habitat are hydrology, sediment transport, energy transfer, nutrient cycling, and delivery of large woody debris. Hydrology is perhaps, the primary "forcing" process at this scale and determines the quantity and timing of streamflow (flow regime) which in turn directly influences sediment transport, channel configuration and habitat availability. Moreover, flow indirectly controls nutrient cycling and energy transfer by affecting the movement of litter, emergence of aquatic insects and the distribution of temperature in the stream environment. The delivery of large woody debris to stream systems illustrates the relationship among process, structure and function quite well. The age and composition of the forest stand (structure) influences the rate of delivery into the stream (process) and also the longevity and interaction of the woody debris with water and sediment (function). The wood, in turn, influences both flow and sediment transport in such a way that pools and riffles are formed, and habitat diversity for salmonids is modified.

An important biological process for Northwest rivers is the migration and spawning of anadromous salmon in our rivers. In the process of spawning, salmon turn over considerable portions of the gravel bed, thus modifying habitat structure to aid survival of their offspring. This activity may also benefit the survival of species that spawn later because fine material is flushed from the stream bed. More importantly, because of our recent glacial history and the presence of our dense coniferous forests, nutrients in our rivers are in short supply. Salmon are a crucial link between oceanic processes and riverine process and structure. Nutrients flushed to the oceans perhaps centuries before are returned in the form of salmon carcasses to nourish bear, mink, elk and deer, and the diversity of aquatic insects that will be food for the next generation of salmon. In fact, recent research has demonstrated that overwintering salmon and trout have significantly higher growth rates in streams where anadromous salmon spawn and die. Some of these nutrients find their way into vegetation within the riparian zone and are taken up by vegetation as diverse as western hemlock and the most appropriately named salmonberry.

The interaction of these processes, at time scales from 1-10,000 years and at landscape scales from reach to region, have produced habitats of unique structure and function suited to a unique family of fishes. The conservation of salmon will ultimately depend upon maintaining and restoring the integrity of these processes at their natural rates and magnitudes or providing structural and functional surrogates for them where ecosystem integrity has been lost.

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RIPARIAN VEGETATION EFFECTIVENESS

By: A.J. Castelle and A.W. Johnson

A common method of reducing or eliminating impacts to streams from nearby land uses is to maintain "buffers" adjacent to the streams. Buffers are vegetated zones located between natural resources (such as streams, wetlands, or critical wildlife habitat) and nearby areas subject to human alteration. In some locations, buffers are known as "vegetated filter strips," or VFSs. The emphasis on the filtering functions of vegetation is derived from their widespread use to remove sediments and other waterborne pollutants from surface runoff.

Many buffer studies have examined the effectiveness of vegetation in maintaining riparian function. Our most recent report graphically summarizes relationships between buffer size and riparian function: this report consists of an extensive literature review and specifically examines the effectiveness of vegetation in providing six riparian functions: three “sink” functions - streambank stabilization, sediment reduction, and chemical removal, and three “source” functions - large organic debris (LOD) production, particulate organic matter (POM) production, and shade production for stream water temperature moderation. Vegetation effects on these functions are mostly described in terms of distance from a stream bank expressed in meters; where appropriate, other metrics are used (such as root density or tree height).

Riparian vegetation sink functions generally increase rapidly with increasing buffer size for buffer widths up to about 25 or 30 m; beyond this size, disproportionately large increases in buffer width are necessary to markedly improve riparian function. For example, with respect to sediment trapping and chemical removal from runoff, most of the benefit of riparian vegetation is manifested within the first five to 25 m. However, sediment trapping and chemical removal vary not only with the width of the vegetated area, but also depend on other factors. For example, live trees promote infiltration and evaporation, thus reducing runoff, while downed trees may provide a significant barrier to sediment movement. The other sink function, streambank stability, is not a function of buffer width. Instead, streambank stability was found to be a function of fine root density within the bank itself, in addition to a function of several intrinsic soil parameters.

Source functions of riparian vegetation were found to be generally highest near streams and decreased with increasing distance from the stream. Vegetated buffers of up to 25 meters in width provide significant LOD, POM, and shade production. As with the sediment trapping and chemical removal curves, disproportionately larger buffers are needed to increase effectiveness for these functions from about 75% to 95% or greater.

Additionally, other site factors, such as flood-prone width, soil physical properties, and side slope gradient above the stream, were found to be important in maintaining riparian function. In some instances, these physical characteristics may be a larger determinant of stream protection than vegetative metrics.

Several investigators have combined biological and abiotic factors in making minimum buffer widths recommendations. For example, the USDA Soil Conservation Service (1982) recommends buffers of 3 to 8 m next to pastures with up to 30 percent slopes, 8 to 46 m near logging operations in areas of 0-70 percent slopes, and 23 to 92 m for livestock feedlots and liquid waste treatment on 2 to 6 percent slopes. Haussman and Pruet (1978) recommended buffers of at least 8 m plus an additional 0.6 m for each 1 percent of slope above streams, with a maximum of 50 m for slopes of 70 percent. Clark (1977) recommended buffers be a minimum 15 m plus 6 m for each 5 percent increase in slope.

Generally, buffer widths for streams may be established using two methods: a fixed width or a variable width that considers specific site conditions. Investigators proposing methods for determining variable buffer widths using a variety of site factors include Darling et al. 1982; Steinblums et al., 1984; Barton et al., 1985; Roman and Good, 1985; Budd et al., 1987; and Groffman et al., 1990. Fixed- or variable-width buffers each have advantages and disadvantages. Fixed-width buffers are more easily established, do not require regulatory personnel with specialized knowledge of ecological principles, and require smaller expenditures of both time and money to administer. This option, however, may result in arbitrary buffer distances that sometimes may not be appropriate.

Variable-width buffers allow greater flexibility for varying site conditions and land management practices for landowners. Variable-width buffers can be tailored to existing site conditions and desired functions, eliminating the need to protect features non-existent in an area. The quality of buffer and site conditions (e.g., quality and age of vegetation, severity of impact, livestock density, or sensitivity of the system to disturbance) should be considered in determining a buffer width. This option may require that professional judgment be employed in the decision-making process, and thus, may not be feasible if experienced personnel are not available. Because of the variability of sites requiring buffers, individual site visits and detailed information are prerequisites for a buffer-width decision. While this is a more costly and time-consuming process, it may protect the environment more completely without causing undue losses to landowners.

In many instances, managing streams via buffers of prescribed widths may not adequately protect the riparian system, and may unnecessarily restrict land uses. Naiman et al. (1992) state that simple prescriptive management, such as riparian zones of fixed width, is less effective than management techniques adapted to local topography and natural disturbance regimes. In other cases, again depending on site conditions and the riparian function to be maintained, a smaller buffer may adequately protect the stream and riparian community.

Generally, there are two types of research needs. The first would entail re-visiting some of the data generated by past studies that examined only one buffer size, but did not study the effects of increasing or decreasing the size of the buffer. Unfortunately, information from such studies may be construed by resource agencies and land managers as minimum guidelines. For example, if a study stated that a 30 m buffer adequately protected streams, it might be inferred that smaller buffers were studied and therefore decide that 30 m buffers should be a minimum standard width. However, if that study were re-visited using buffers of 15, 10, 15, and 20 m, it might be determined that somewhat smaller buffers may be as or nearly as effective, particularly for specific riparian functions. As an alternative to studying varying buffer widths, other buffer zone management practices should be investigated. For example, stand composition could be manipulated to favor tree species which provide exposed roots (for sediment trapping), high transpiration rates (for nutrient uptake), and broad canopies (for shade production).

The second type of research needed should focus on the interactions between vegetative and non-vegetative factors. Depending on site-specifics, and on the nature and degree of potential impacts, it might be determined that abiotic factors are more important than vegetation in determining buffer effectiveness. These various factors can be isolated and studied in laboratory or other controlled settings, but in nature all biotic and abiotic factors work together, and isolating individual parameters provides insight into only artificial environments.

RESTORING LIFE IN RUNNING WATERS; PLANNING THAT SEES THE SALMON LANDSCAPE

By: James R. Karr

For more than 100 years, human society in the Pacific Northwest has watched as salmon populations have declined; many stocks are extinct. Although the declines have been much discussed and many actions have been taken to reverse the trend, the trend nonetheless continues. The potential Endangered Species Act (ESA) listing of Puget Sound Chinook adds urgency to the discussion and emphasizes the effects of urbanization on salmon numbers. Efforts to avoid this and other potential listings under ESA proliferate. Because of the long history of failure to reverse long-term trends in salmon numbers, it seems prudent to examine carefully any and all efforts to produce a new generation of “fixes.” More important, perhaps, we should carefully examine the theoretical underpinnings, the hypotheses if you will, that have been or will be used to guide efforts to reverse the trend.

One such hypothesis is captured in the subtitle of this symposium, “Can habitat in the path of development be saved?” I suggest that the question itself will lead us astray because it provides for a new generation of narrow conceptions of the challenge. Rather than saving habitat, for example, should we focus on saving salmon, or fish? Better yet should our focus be on the complex living systems that salmon and other fish depend on?

Or should we think more comprehensively about the landscapes that salmon depend on for their survival? That landscape clearly includes rivers, their watersheds, and the ocean environments where salmon reside through much of their life cycle. But the salmon landscape also includes the administrative and political landscapes that salmon must traverse in their migrations. And those landscapes are created by the attitudes and philosophies of the people that occupy the Pacific Northwest. Failure to focus on any of these dimensions of the salmon landscape is likely to limit the success of policies to protect and restore salmon. Clearly, saving habitat in the path of development will not be enough, just as making baby fish or clean water is not enough.

Efforts to protect and restore the salmon landscape, and thus protect salmon populations, should keep several lessons from the pat in mind. First, we must overcome narrow conceptions of the challenge and the legacies that come from those conceptions. Second, we must be realistic. We should strive for better rivers everywhere, not salmon everywhere. Furthermore, we should recognize that we can’t repair 100+ years of damage in 5 to 10 years. Third, we should recognize that knowledge is, and always will be, limited. At the same time, we know enough today to do a better job of protecting salmon landscapes and thus salmon. Fourth, we must begin to establish priorities in a more comprehensive and incisive way. Decisions to protect the best (conservation), develop intelligently (development), and restore the rest (restoration), must be guided by thoughtful integration of scientific information, economic consequences, and the values and attitudes of the people.

Decisions derived from this integration should focus on three questions: How do we decide what to do? How do we decide where to do it? How do we decide if it worked? Sadly, the last question has rarely been included in past analyses.

Because a biological endpoint—protection of salmon populations and the life-support systems they depend on-is a core goal, we must do a better job of documenting the biological effects of our actions. That is, we must select appropriate biological indicators as endpoints for monitoring and evaluation. Better biological monitoring is key to the evaluation of past approaches, to the protection of valuable natural resources, and to avoid the waste of economic resources in programs or practices that simply do not work.

Better biological monitoring is key to restoring life in running waters—including salmon. No matter how important for commerce, sport, or even as a regional icon a particular species is to humans, it cannot persist outside the biological context that sustains it. Failing to protect plankton, insects, bacteria, higher plants, or other fish ignores the key contributions of these taxa to health living systems. Salmon depend on healthy living systems.

Human activities—urbanization, grazing, logging, point and non-point pollution, and others—do not just degrade "habitat." Human activity alters water quality, habitat structure, flow regime, sources of energy and nutrients for the aquatic food web, and biotic interactions. Analyses to conserve, develop, or restore must incorporate this broader perspective on the consequences of human actions. Those analyses must focus on biological endpoints.

Because they focus on living organisms—whose very existence represents the integration of conditions around them—biological evaluations can diagnose chemical, physical, and biological impacts as well as their cumulative effects. One biological yardstick is the index of biological integrity (IBI), first developed in 1981 for monitoring water resource condition in Midwestern US streams. The IBI has now been adopted for use in evaluation of the condition of streams in Puget Sound. Like economic indexes an IBI consists of multiple measures—called metrics—each describing one aspect of the biological condition of a site. Each measure should be sensitive to important characteristics of living communities, not narrow indicators of commodity production or of threatened and endangered status. Together, such measures make up an ecological yardstick. Changes in those measures, like the changes in temperature or altered blood cell counts in a human, signal "ecological disease."

Samples of invertebrates from one of the best streams (Rock Creek) in rural King County, Washington, for example, contained 27 kinds (taxa) of invertebrates; similar samples from an urban stream (Thorton Creek) in Seattle contained only 7 taxa. The rural stream has 18 taxa of mayflies, stoneflies, and caddisflies, the urban stream only 2 or 3. When these and other metrics are combined in an index based on invertebrates, the resulting "benthic index of biological integrity" (B-IBI) provides a numeric description of the condition, or health, of a stream. The B-IBI for Rock Creek was 44 (maximum index is 50) and that for Thorton Creek was 10 (minimum 10). Based on our preliminary analyses of these and 25 to 30 other Puget Sound lowland streams, it appears that B-IBI values below about 35 to 38 are not likely to support healthy populations of coho salmon. This numeric index makes it possible to compare steam quality across geographic areas so that citizens as well as managers can establish priorities for protection and restoration. Biological monitoring and assessment in this framework can provide a powerful tool to answer the "how to decide" questions mentioned above.

LAKE WASHINGTON: FISHERIES IMPACTS AND OPPORTUNITIES

By: Gino Lucchetti and Cleve Steward

INTRODUCTION

In this paper we present an overview of the Lake Washington watershed and its fishery resources to illustrate the generic impacts of urban development and to suggest ways in which the watershed can be protected for the benefit of future generations. For its size, the Lake Washington drainage basin is the most heavily urbanized area in the Pacific Northwest. As a case history, it offers many examples of success and failure in natural resource management. The clean-up of Lake Washington in the 1960s is one of the best known examples of successful restoration in the world and shows what a region can do with good science and willing people. However, the watershed also contains numerous examples of failed resource management efforts that underscore the difficulty of protecting and restoring natural values in the face of burgeoning population growth.

Fortunately, Lake Washington continues to support comparatively large runs of salmon. The lake owes its continued productivity to a variety of factors, not the least of which is that the three primary fish-producing streams-the Cedar River, and Bear and Issaquah Creeks-still provide significant amounts of high quality fish habitat. In addition, Lake Washington is a remarkably clean lake, due in large part to the high water quality provided by the Cedar River, the upper two-thirds of which is in a municipal watershed protected from development. Although the upper Cedar River should continue to enjoy protected status, water quality and salmon populations in the Lake Washington watershed as a whole are expected to decline unless protection and restoration measures are implemented soon.

PHYSICAL SETTING

The Lake Washington watershed comprises 530 square miles, within which may be found Washington and Sammamish Lakes – the second (22,000 acres) and seventh (4,900 acres) largest lakes, respectively, in Washington State. Lake Washington is fed by the Cedar River and the smaller Sammamish River, which drains Lake Sammamish. Bear Creek enters Sammamish River downstream of the lake outlet. The major tributary to Lake Sammamish is Issaquah Creek, which, like the Cedar River, headwaters in the Cascade Mountains at elevations of about 5,000 feet. The Cedar River, Bear Creek, and Issaquah Creek are the major salmon-bearing streams within the Lake Washington watershed. Smaller streams with significant habitat include: Little Bear, North and Swamp Creeks – tributaries to the Sammamish River; May and Kelsey Creeks – tributaries to Lake Washington; and Rock, Peterson, and Taylor Creeks and the Walsh Lake Diversion – tributaries to the lower Cedar River. An additional 13 miles of extremely high quality habitat in the Cedar River is expected to be available for chinook and coho salmon and steelhead trout within the next five years when the City of Seattle provides passage above its Landsburg Diversion Dam.

The region's climate is moderate; dry summers and moist winters are typical, with annual precipitation ranging from 30 to 50 inches in the lower elevations to as much as 200 inches in the higher elevations. The topography of the river valleys and lakes was primarily shaped by glaciation as recently as 14,000 years ago. Glaciers sculpted the land and deposited a heterogeneous mix of porous glacial outwash sediments and less porous till. An understanding of this geologic legacy is key to assessing human impacts and future restoration options.

HISTORIC CHANGES

The Lake Washington watershed has undergone dramatic changes since it was first settled by Europeans in the mid-1800s. Coal mining, logging, railroad and road construction, and homesteading were among the early activities. Efforts were underway by the last quarter of the century to reroute rivers and divert water for municipal and industrial water supply. Originally Lake Washington drained at its south end via the Black River, to which the Cedar River was a tributary. The Black River merged with the Green and White River to form the Duwamish, which entered Puget Sound at Elliot Bay. By 1900, the City of Seattle had constructed holding and diversion dams to withdraw water from the Cedar River. Since that time, about 27% of the Cedar River flow has been diverted for Seattle and its customers. In 1906, flow in the Duwamish was reduced by about a third when the White was diverted into the Puyallup River.

Construction of the Lake Washington Ship canal and the H.M. Chittenden Locks (a.k.a. Ballard Locks) was completed by 1916, creating a new outlet for Lake Washington. As a consequence, water levels in Lake Washington dropped nine feet, effectively eliminating outflow via the Black River and reducing Duwamish flows by another third. The lower 2 miles of the Cedar River was channelized and diked to drain a large wetland and facilitate commercial development in the vicinity of what is now the City of Renton. Unfortunately, the channel was improperly sited and constructed, creating costly maintenance problems that continue to this day. The final major river alteration occurred in the mid-1960s, when the Sammamish River, formerly comprising 27 miles of meandering reaches, backwater sloughs, and wetlands, was shortened to 14 miles of highly confined channel.

HISTORY OF LAND DEVELOPMENT

Initially confined to the City of Seattle, urban development has spread throughout much of the Lake Washington watershed over the past 150 years. Today, about 1 million people live in the watershed, mostly in Seattle (about 33% of the total population), unincorporated King County (25%), and Bellevue (10%). The remainder reside in twenty-one smaller cities in King and Snohomish Counties, principally along the shorelines of Lake Washington and Lake Sammamish and near the mouths of the region's major rivers and tributaries, such as the Cedar and Sammamish Rivers, and Big Bear, Issaquah, Kelsey and May Creeks.

Population growth has been accompanied by an increase in impervious surface area in the watershed, mostly as a result of road and building construction. Today, approximately 18% of the Lake Washington/Cedar River subwatershed and 14% of the Lake Sammamish/Sammamish River subwatershed are either paved or otherwise rendered impervious. Most of the impervious area is concentrated along the shorelines of the two large lakes and the mouths of the large tributaries.

Helping to offset the effects of urban sprawl are large areas of protected natural forest, including 128 square miles of the upper Cedar, regional parks on Tiger, Cougar, and Squawk Mountains, and smaller parcels of land set aside as parks by local municipalities. Together, these reserves provide significant protection in headwater reaches of the Cedar River and Issaquah Creek. Bear Creek headwaters are not in protected status and remain at high risk of development.

UNDERSTANDING AND CONTROLLING LAND DEVELOPMENT

Much of what we know about the impacts of urban development in the Pacific Northwest derives from seminal studies conducted by researchers from the University of Washington in the late '70s and early '80s. The studies focused on two lake Washington tributaries: Kelsey and Bear Creeks. Kelsey Creek drains much of the City of Bellevue and exhibits physical and chemical characteristics typical of urban streams. Bear Creek at the time was still relatively undeveloped, and so could be used as a reference or "control" stream. Significant differences in flow, habitat structure, water quality, benthic invertebrates and fish populations were detected. These initial observations have been confirmed and elaborated upon since then.

As development accelerated over the ensuing two decades, it became clear that urbanization posed threats not only to fish but also to public safety. Injudicious land use and channel modifications caused significant erosion, sedimentation, and flooding problems. Early attempts to control drainage by, for example, the construction of stormwater retention ponds, were largely inadequate, and costly erosion and flooding problems persist in many areas. Our inability to maintain or mimic natural processes using technological means does not bode well for the future of aquatic resources in the Lake Washington watershed. Other more ecologically-sound approaches must be found to restore and protect the functional, structural, and compositional integrity of the urban land-water system.

TODAY'S FISH POPULATIONS – MORE THAN A REMNANT

Despite its history of development, the Lake Washington watershed remains remarkably productive for salmon. The Lake Washington watershed has the potential to produce over 500 adult spawners per square mile of watershed area for four major salmon species combined (sockeye, chinook, coho and steelhead), over twice that of the next most productive river entering Puget Sound. Much of this productivity is due to the large run of sockeye entering Lake Washington – the largest aggregation of spawning sockeye occurring south of the Canadian border. Along with sockeye, chinook, coho, and steelhead, the watershed is home to populations of cutthroat, rainbow, and bull trout and a diverse assemblage of native and exotic fishes.

Several genetically unique subpopulations of salmon persist in the watershed, including Bear Creek sockeye, Lake Sammamish kokanee (a form of landlocked sockeye), Cedar River chinook, and Lake Washington steelhead. Due to recent downward trends in abundance, Cedar River chinook were identified along with several other Puget Sound chinook populations earlier this year by the National Marine Fisheries Service as a candidate for listing under the Endangered Species Act.

Salmon returning to the Cedar River are managed primarily for natural production; the Cedar is one of the few rivers in Puget Sound that lacks a permanent salmon hatchery. Fisheries management policies and regulations also aim to protect the aforementioned populations of Bear Creek sockeye and Lake Washington steelhead and, more generally, all salmonid populations residing in the lakes’ smaller tributaries. Chinook and coho salmon bound for the Lake Sammamish drainage originate primarily from the Issaquah salmon hatchery, located on Issaquah Creek a short distance upstream from its mouth. Fisheries regulations allow for higher harvest of these hatchery-derived fish than would be feasible for sustainable wild runs. For many years natural spawning in Issaquah Creek was reduced by the hatchery weir; only recently have significant numbers of salmon been allowed to migrate upstream of the hatchery and spawn naturally. The broader impacts of this hatchery on the productivity of the watershed’s wild salmon are unknown.

Unfortunately, many runs of salmon that formerly returned to smaller streams in the Lake Washington watershed have been reduced to remnant status or extirpated altogether. In some streams, such as Ravenna Creek, large reaches have been piped and upstream passage has been blocked. Other streams such as Thornton Creek, which enters Lake Washington, and Madsen Creek, a Cedar River tributary, support only a few species of fish, and only rarely are anadromous salmon observed in them.

Coho salmon, which have all but disappeared from streams in heavily developed drainages, are a sensitive barometer of human-caused disturbances. Because coho spawn in the fall, their eggs are highly vulnerable to winter freshets. Coho juveniles also rely on large woody debris and off-channel habitats for concealment and refuge; these features have become increasingly rare in the urban setting, so too have coho salmon. Efforts to restore salmon in urban streams by reducing drainage impacts, restoring habitat, and stocking hatchery fish have been ineffectual at restoring spawning populations. However, reducing hydrologic extremes and improving habitat features holds promise for reducing drainage problems and incrementally improving habitat for fish adapted to urban settings.

At least one species of salmonid, the cutthroat trout, has displayed remarkable resiliency in the face of encroaching development. That cutthroat are able to persist in all but the most heavily impacted streams may be attributable to its unique life history and ecology. Cutthroat are smaller-bodied than coho salmon and are capable of spawning in smaller patches of gravel. They also spawn in the spring when flooding is less prevalent, so their eggs are less likely to be damaged by bed movement or scoured from the streambed. Moreover, juvenile cutthroat are adapted to living in high energy streams that lack large well-developed pools. For some low gradient urban streams, low coho spawning escapements due to the combination of poor ocean conditions, overharvest and hatchery interactions, may also be contributing to the dominance of cutthroat because cutthroat trout do better in the absence of coho salmon.

FACTORS CONTRIBUTING TO HEALTHY RUNS AND FUTURE THREATS

The rivers and streams that currently support healthy salmon populations in the Lake Washington watershed share the following attributes: they drain catchments having relatively undeveloped headwaters, largely intact riparian corridors, and a high number of functional riparian and headwater wetlands; they contain a diversity of high quality in-channel and floodplain habitat types; and they exhibit flow, sediment, and temperature regimes that are within the normal range of salmon adaptability.

When one considers recent trends in development, there is little reason to believe that productivity in the watershed will remain at current levels unless protective and restorative measures are taken soon. Although the headwaters of the Cedar River and Bear and Issaquah Creeks are for the most part unaffected by development, their riparian corridors and floodplains are highly vulnerable. Urban growth within these environmentally sensitive areas will need to be controlled if their fish populations are to remain healthy.

PROTECTION AND RESTORATION EFFORTS

Local, state, federal, and tribal governments are combining their expertise and resources to address the critical needs of salmon. Comprehensive basin plans have been developed for all resource-rich basins in the Lake Washington watershed. These plans have helped to identify surface water management problems and solutions, and broad strategies for protecting aquatic habitats and associated biological communities. The highest priority is to protect the best remaining habitat by acquiring land, implementing special regulations and cooperative management agreements, developing stewardship incentives (e.g., conservation easements), and prohibiting and removing development.

Habitat and water quality improvement and flood hazard abatement projects have been identified and prioritized based on local and regional goals and constraints. Watershed Forums have been formed for the Lake Washington/Cedar and Sammamish portions of the watershed. Programs such as Waterways 2000, Cedar River Legacy, the Lake Sammamish Initiative, and the City of Seattle's Habitat Conservation Plan have spent (or will spend) millions to protect and restore habitat and involve the public through educational and hands-on projects.

RECOMMENDATIONS

The recovery and long-term persistence of salmon populations in the Lake Washington requires a scientifically-sound, integrated approach to managing salmon and habitat. Without adequate funding and long-term community and political support, success will elude us. Priority should be given to the protection of existing high quality habitats. These areas, which are typically found in the headwater reaches, perform critical functions that must be protected. But relatively undisturbed lower stream reaches and off-channel areas should also be protected. It will be easier in the short run and less costly in the long run to protect high quality habitat rather than attempt to restore degraded habitat.

That being said, it is critical to identify and ameliorate factors that impede the movements of salmon, destroy their habitat, or kill disproportionate numbers of them at specific places or times. Examples include impassable culverts and catastrophic inputs of sediment and pollutants. Restoration efforts will need to be coordinated within and across catchments to achieve the best results. Monitoring programs should be developed to evaluate the effectiveness of our efforts and to obtain information that can be used to guide future management.

WATERSHED URBANIZATION AND THE DECLINE OF SALMON IN PUGET SOUND STREAMS

By: Richard R. Horner and Christopher W. May

ABSTRACT

The Puget Sound lowland (PSL) ecoregion contains an abundance of complex and historically productive salmonid habitat in the form of small stream ecosystems, including their riparian forests and wetlands. These watersheds are under intense pressure owing primarily to the cumulative effects of urban development. Urbanization of PSL watersheds has increased impervious areas and decreased forested areas, including a significant loss of natural riparian forests and wetlands. The cumulative effects of a modified hydrologic regime, the loss of instream structural complexity, and the alteration of channel morphological characteristics accompanying urbanization have degraded instream habitat and biological integrity in PSL streams. At very low levels of development there appears to be a rapid decline in biological integrity as well as the physical habitat conditions necessary to support natural biological diversity and complexity. This decline continues as watershed development increases, with no threshold indicated. These results suggest that resource managers should place a high priority on preservation and protection of high-quality stream ecosystems that currently support natural salmonid populations. Mature, riparian forests dominated by coniferous trees should be the long-term management goal. A wide and near-continuous riparian zone appears to be a necessary, although not wholly sufficient condition for a natural level of ecological integrity. Rehabilitation and enhancement efforts should be concentrated on streams draining watersheds with low to moderate development. Restoring the natural hydrologic regime should be a primary goal. At the highest levels of urbanization, natural ecological function may not be possible. Although recovery to near-pristine conditions cannot be expected in all developed stream basins, innovative mitigation efforts should nevertheless continue in an effort to improve stream quality to a level supportive of natural biota. Because of the cumulative effects of past and current land-use practices, some habitat enhancement will be required to accomplish rehabilitation goals in all PSL streams, regardless of present watershed development level. Under current development and mitigation strategies, it is apparent that downstream changes to both the structure and function of aquatic ecosystems is inevitable unless limits are instituted on the extent and distribution of watershed development.

BACKGROUND

In the Pacific Northwest (PNW), as in many areas of North America, urban development is rapidly expanding into areas containing much of the remaining natural aquatic ecosystems. In the Puget Sound lowland (PSL) ecoregion, the natural ecosystems most directly affected by urbanization are small streams and associated wetlands. These ecosystems are critical spawning and rearing habitat for several species of native salmonids (both resident and anadromous), including cutthroat trout (*Oncorhynchus clarki*), steelhead trout (*O. mykiss*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), chinook salmon (*O. tshawytscha*), pink salmon (*O. gorbuscha*), and sockeye salmon (*O. nerka*). These fish, especially the salmon species, are of great ecological, cultural, and socio-economic value to the peoples of the PNW. Despite this value, wild salmonids are in considerable jeopardy of being lost to future generations (Figure 1). Over the past century, salmon have disappeared from about 40% of their historical range, and many of the remaining populations (especially in urbanizing areas) are severely depressed (Nehlsen et al., 1991). There is no one reason for this decline. The cumulative effects of land-use practices, including timber harvesting, agriculture, and urbanization, have all contributed significantly to this widely publicized “salmon crisis.”

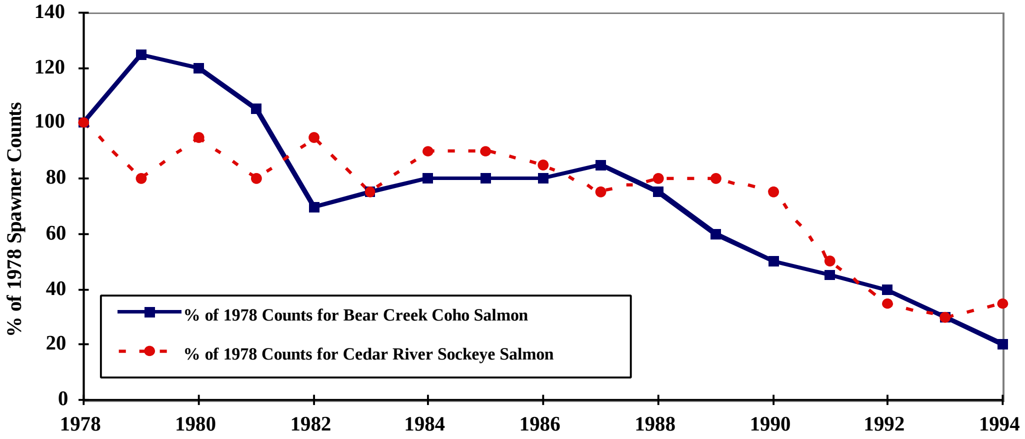

Figure 1. Representative data showing the decline in salmon stocks in the Puget Sound lowland (PSL) region, using 1978 as the base year for spawner counts (Washington State Department of Fisheries data).

The effects of watershed urbanization on streams are well documented (Leopold, 1968; Hammer, 1972; Hollis, 1975; Klein, 1979; Arnold et al., 1982; Booth, 1991). They include extensive changes in basin hydrologic regime, channel morphology, and physiochemical water quality. The cumulative effects of these alterations has produced an instream habitat that is significantly different from that in which salmonids and associated fauna have evolved. In addition, development pressure has a negative impact on riparian forests and wetlands, which are essential to natural stream functioning. Considerable evidence of these effects exists from many studies of urban streams in the PNW (Perkins, 1982; Richey, 1982; Steward, 1983; Scott et al., 1986; Booth, 1990; Booth and Reinelt, 1993; Taylor, 1993). Nevertheless, most previous work has fallen short of establishing cause-and-effect relationships between physical and chemical variables resulting from urbanization and the response of aquatic biota.

The most obvious manifestation of urban development is the increase in impervious surface area and the corresponding loss of natural vegetation. Land clearing, soil compaction, encroachment on riparian corridors, and modifications to the surface-water drainage network all typically accompany urbanization. Watershed urbanization is most often quantified in terms of the proportion of basin area covered by impervious surfaces (Schueler, 1994; Arnold and Gibbons, 1996). Although impervious surfaces themselves do not generate pollution, they are the major contributor to the change in basin hydrologic regime that drives many of the physical changes affecting urban streams. Basin imperviousness and stormwater runoff are directly related (Schueler, 1994). The two most common measures of imperviousness are total impervious area (%TIA) and effective impervious area (%EIA). The distinction between the two lies in the linkage between the impervious surface and the drainage network. Total impervious area includes all impervious surfaces in the watershed. Effective impervious area includes only those that are directly connected to the surface drainage system. Total and effective basin imperviousness are typically proportional to each other (Alley and Veenhuis, 1983; Beyerlein, 1996). In previous studies, a TIA of about 10% has been identified as the level at which impairment of the stream ecosystem begins (Klein, 1979; Steedman, 1988; Schueler, 1992; Booth and Reinelt, 1993). Recent studies also suggest that this potential threshold may apply to wetlands as well (Taylor, 1993; Horner et al., 1996).

STUDY DESIGN

A key objective of the PSL stream study was to identify the links between landscape-level conditions and instream environmental factors. This objective included defining the functional relationships between watershed modifications and aquatic biota. The goal was to provide a set of stream-quality indices for local resource managers to use in managing urban streams and minimizing resource degradation due to development pressures. The assumption is that given populations or communities of organisms (native salmonids) can be maintained at a specified level by sustaining a certain set of habitat characteristics, which, in turn, depend on an established group of watershed conditions. An additional objective was to identify any possible thresholds of watershed urbanization related to instream salmonid habitat and aquatic biota. The study was designed to establish the links between landscape-level conditions, instream habitat characteristics, and biological integrity. A conceptual model of this design is illustrated below:

Watershed and Riparian Characteristics **Þ** **Instream Habitat Conditions** **Þ** **Aquatic Biota**

A subset of 22 small-stream watersheds (Figure 2) was chosen that represented a range of development levels from relatively undeveloped (reference) to highly urbanized. Total impervious surface area, because of its integrative nature, was used as the primary measure of watershed urbanization. The attributes of the stream catchments were established using standard watershed analysis methods, including data from geographic information systems (GIS), aerial photographs, basin plans, and field surveys. Impervious surface coverage, riparian integrity, physical characteristics of the instream habitat, chemical water-quality constituents, and aquatic biota were analyzed on both watershed and stream-segment scales. Streamflow was continuously monitored by local agencies on 10 of the study streams. Chemical water-quality monitoring (baseflow and storm events) was conducted at 23 sites on 19 of the study streams. Biological sampling (macroinvertebrates) was performed in 31 reaches on 21 of the study streams. Extensive surveys of instream physical habitat and riparian zone characteristics were made on 120 stream segments that included all 22 PSL streams; each survey represented local physiographic, morphologic, and sub-basin land use conditions from the headwaters to the mouth of each stream. Salmonid abundance data were obtained from public, private, and tribal sources.

All streams were third order or smaller, ranging in basin area from 3 to 90 km^2, with headwater elevations less than 150 m. Stream gradients were less than 3.5% (most were < 2%). The study watersheds represented the two general types of geologic and soil conditions found in the Puget Sound region. These types are mainly a result of the last glacial period (15,000 years ago). All but three of the watersheds were dominated by poorly drained glacial till soils, with the remaining basins being dominated by glacial outwash soil types (moderately well drained). In the undisturbed, natural forested condition, PSL catchments are capable of providing adequate natural storage of precipitation in the surficial “forest-duff,” and little runoff results. Therefore, in natural PSL watersheds a subsurface-flow hydrologic regime dominates. Development typically strips away this absorbent layer, compacts the underlying soil, and exposes the underlying till. Also lost is a significant amount of interception storage as well as evapo-transpiration potential provided by the regionally dominant coniferous forest. The typical suburban development in the PNW has been estimated to have roughly 90% less storage capacity than naturally forested areas (Wigmosta et al., 1994). The latest (1990) stormwater mitigation and best-management practices (BMPs) would, at most, recover only about 25% of the original storage capacity (Barker et al., 1991). Because these standards affected very little new development that occurred between 1990 and the start of this study in 1994, the basin conditions observed largely reflected the pre-1990 situation, and little effective stormwater control was present. Therefore, no significant conclusions could be drawn from this research about the effectiveness of current stormwater controls (BMPs) and regulations.

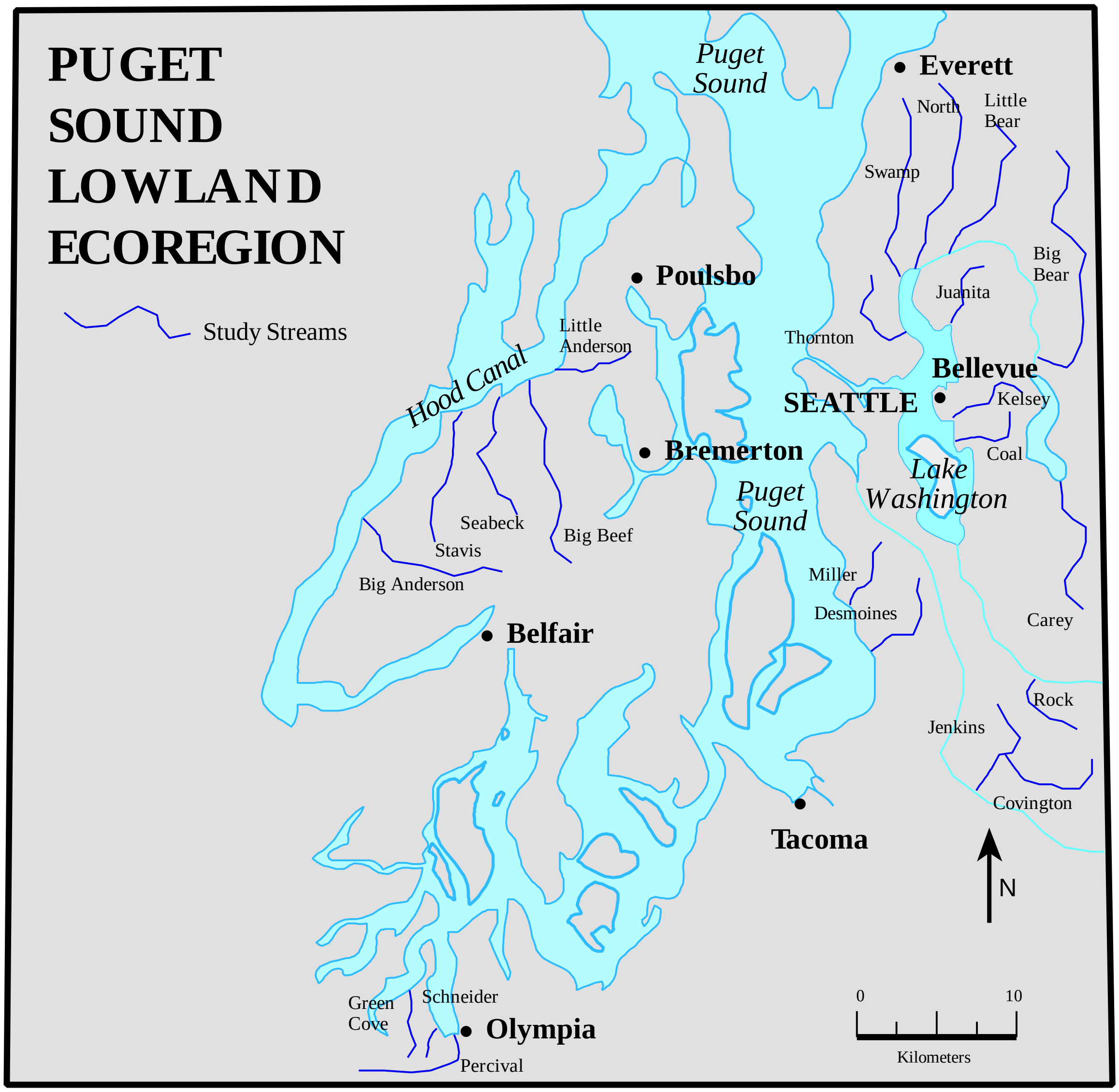

Figure 2. Puget Sound lowland (PSL) ecoregion

RESULTS AND DISCUSSION

Watershed Conditions

Watershed imperviousness ranged from undeveloped (TIA < 5%) to highly urbanized (TIA > 45%). Imperviousness (%TIA) was the primary measure of watershed development; however, other measures of urbanization were investigated. Calculating impervious surface area can be costly, especially if computerized methods like GIS are utilized. In addition, the land-use data required for calculating %TIA may be unavailable or inaccurate. As part of this study, a low-cost alternative to using impervious area was also investigated. Analysis demonstrated that results were very similar whether development was expressed as impervious area or as road density (Figure 3). This is especially relevant in that the transportation component of imperviousness often exceeds the "rooftop" component in many land-use categories (Schueler, 1994). A recent study in the Puget Sound region has shown that the transportation component typically accounts for over 60% of basin imperviousness in suburban areas (City of Olympia, 1994).

The PSL study (Cooper, 1996) confirmed that watershed urbanization significantly changes basin hydrologic regime (Leopold, 1968; Hollis, 1975; Booth, 1991). The ratio of modeled 2-year stormflow to mean winter baseflow (Cooper, 1996) was used as an indicator of development-induced hydrologic fluctuation (Figure 4). This discharge ratio is proportional to the relative stream power and thus is representative of the hydrologic stress on instream habitats and biota exerted by stormflow conditions relative to baseflow conditions. Modification of basin hydrologic regime was found to be one of the most influential changes resulting from watershed urbanization in the PSL region.

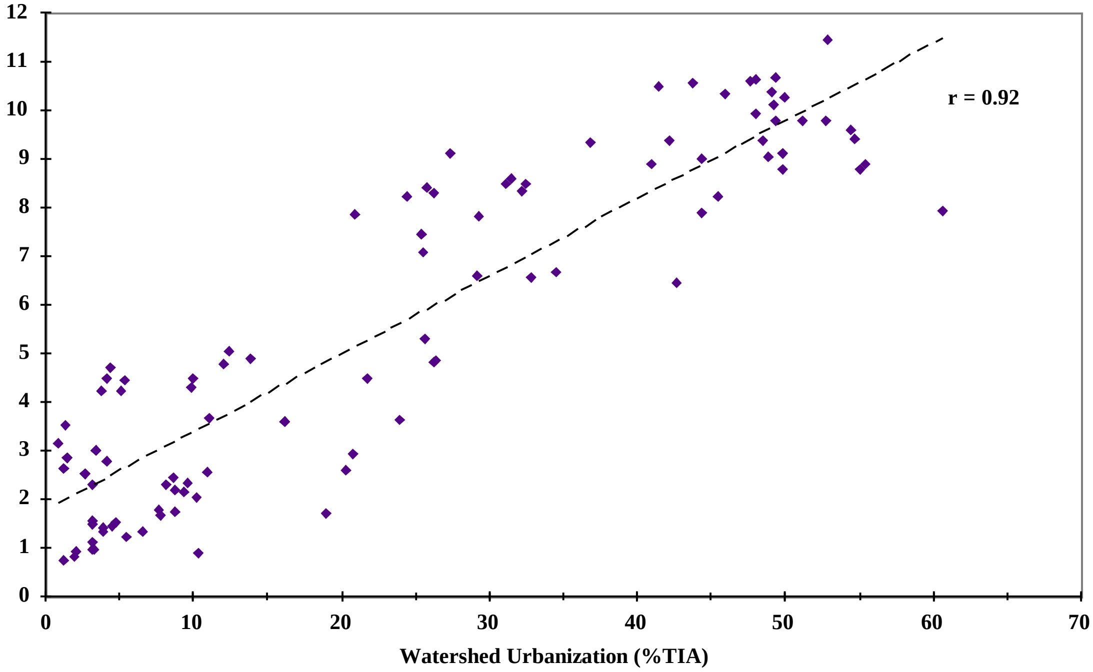

Figure 3. Relationship between urbanization (%TIA) and sub-basin road density in Puget Sound lowland (PSL) streams.

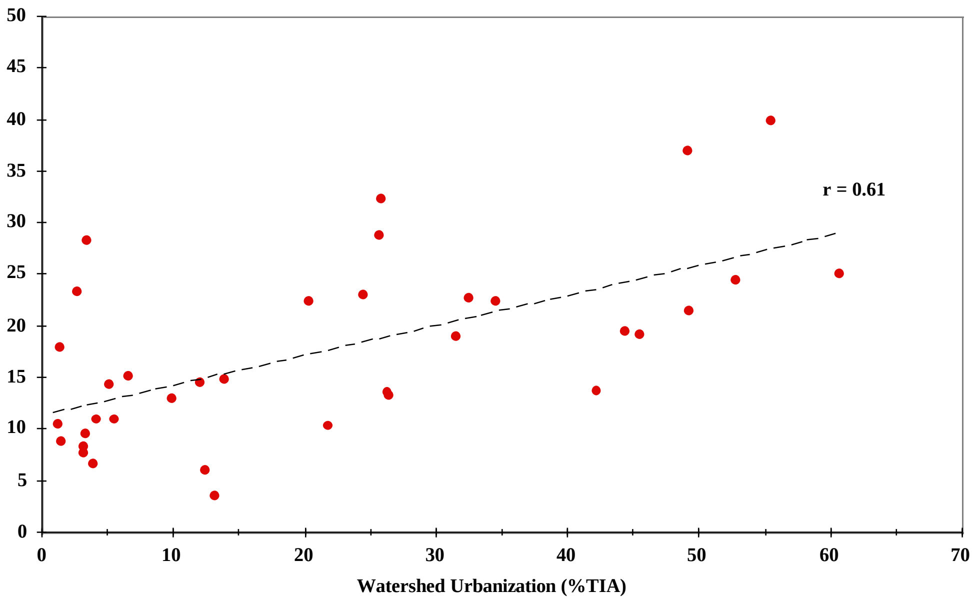

Figure 4. Change in basin hydrologic regime with urbanization in Puget Sound lowland (PSL) streams as indicated by the ratio of 2-year stormflow to winter baseflow.

In addition to increasing basin imperviousness and the resulting stormwater runoff, urbanization also affects watershed drainage density (kilometers of stream length per square kilometer of basin area). This was first investigated by Graf (1977). In the PSL study, natural, predevelopment drainage density (DD) was calculated using historic topographic maps. This was then compared with the current, urbanized DD, which included the loss of natural stream channels (mostly first-order and ephemeral ones) due to grading or construction and the increase in artificial "channels" due to road crossings and stormwater outfalls. The ratio of urban-to-natural DD was used as an indicator of urban impact (Figure 5).

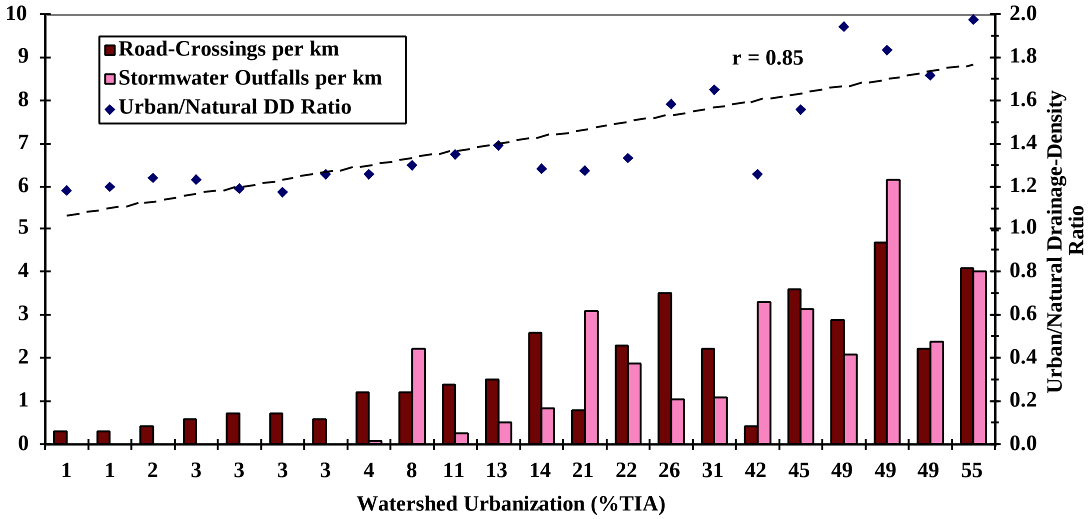

Figure 5. Change in watershed drainage density (DD) due to the effects of urbanization on the stream channel network.

Riparian Conditions

The natural riparian corridors along PNW streams are among the most diverse, dynamic, and complex ecosystems in the region. Natural riparian integrity in the PNW is characterized by wide buffer zones, a nearly continuous corridor, and vegetation dominated by a mature, coniferous forest. Riparian corridors are key features that significantly control environmental conditions in stream ecosystems (Naiman, 1992). The extent of the riparian zone, the level of control that it exerts on the stream environment, and the diversity of its functional attributes are mainly determined by the size of the stream and its longitudinal position within the drainage network (Naiman et al., 1993). Well developed, morphologically complex floodplains are often an integral part of the riparian corridors surrounding PNW streams and rivers (Naiman, 1992). The riparian corridor is frequently disturbed by flooding, creating a naturally complex landscape. Ecological diversity in riparian zones is maintained by the natural disturbance regime (Naiman et al., 1993).

Not surprisingly, riparian conditions were also strongly influenced by the level of development in the surrounding landscape. The impact of development on riparian corridors varies widely, depending on the type and intensity of land use, the degree of disturbance to streamside vegetation, and the residual integrity of the riparian zone. Under past land-use practices, increased development has led to a decrease in the width of the of buffer zone, fragmentation of the riparian corridor, and an overall degradation in riparian quality. In general, until 1993, development regulations in the PNW did not specifically address riparian buffers. Sensitive-area ordinances, now in effect in most local municipalities, typically require riparian buffers 30–50 m (100–150 ft) wide. These recently adopted regulations had little influence on the urbanized streams in the PSL study. In general, wide riparian buffers were found only in undeveloped or rural watersheds (Figure 6). The actual size of riparian buffer needed to protect the ecological integrity of a stream system is difficult to establish (Schueler, 1995). In most cases, the minimum buffer width "required" depends on the resource or use of interest and the quality of the existing riparian vegetation (Castelle et al., 1994).

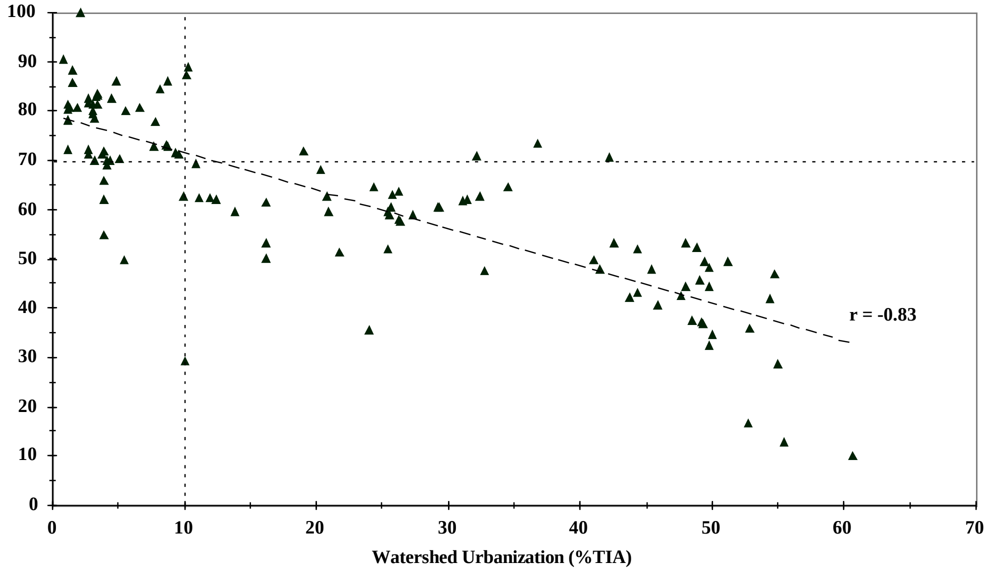

Figure 6. Relationship between riparian buffer width and basin urbanization (%TIA) in Puget Sound lowland (PSL) streams.

Encroachment into the riparian buffer zone is pervasive, continuous, and extremely difficult to control. At the same time, riparian forests and wetlands, if maintained, appear to significantly mitigate some of the adverse effects of development. A buffer width of less than 10 m is generally considered functionally ineffective (Castelle et al., 1994). The fraction of riparian buffer less than 10 m wide was used as a measure of riparian zone encroachment. In general, only natural, undeveloped basins (TIA < 10%) had streams where less than 10% of the buffer zone was in a nonfunctional condition. As watershed urbanization (%TIA) increased, riparian buffer encroachment also increased proportionally. For the most highly urbanized streams (TIA > 40%) in this study, generally more than 40% of the buffer zone was in a nonfunctional condition.

The longitudinal continuity of the riparian corridor is at least as important its lateral width. A nearly continuous riparian zone is the typical natural condition in the PNW (Naiman, 1992). The riparian corridor in urban watersheds can become fragmented from a variety of human influences; the most common and potentially damaging being road crossings. In the PSL stream study, the number of stream crossings (roads, trails, and utilities) increased in proportion to the intensity of basin development. All but one undeveloped stream (TIA < 10%) had, on average, less than one riparian break per kilometer of stream length. Of the highly urbanized streams (TIA > 40%), all but one had more than two breaks per kilometer. Based on current development patterns in the PSL, only rural land use consistently has less than two breaks in the riparian corridor per kilometer of stream length. In general, the more fragmented and asymmetrical the buffer, the wider it needs to be to perform the desired functions (Barton et al., 1985).

The riparian zone was also examined on a qualitative basis. Mature forest, young forest, and riparian wetlands were considered "natural" as opposed to residential or commercial development. From an ecological perspective, mature forest and riparian wetlands are the two most ecologically functional riparian conditions in the PNW (Gregory et al., 1991). In the 22 PSL streams, riparian maturity was also found to be strongly influenced by watershed development. Only in natural streams (TIA < 5%) was a substantial portion of the riparian corridor mature forest (40% or greater), whereas urban streams consistently had little mature riparian area. In addition, none of the urbanized PSL streams retained more than 25% of their natural floodplain area.

Chemical Water Quality

Chemical water-quality constituents were monitored under baseflow and stormflow conditions. Baseflow conductivity was found to be strongly related to the level of basin development (Figure 7). Coal Creek was a confirmed outlier owing to the residual effects of historical coal mining in its headwaters. While conductivity is a nonspecific chemical parameter, it is a surrogate for total dissolved solids and alkalinity and an excellent indicator of the cumulative effects of urbanization (Olthof, 1994). Storm event mean concentrations (EMC) of several chemical constituents were found to be related to both storm size (magnitude and intensity) and basin imperviousness (Bryant 1995). However, water-quality criteria were rarely violated except in the most highly urbanized watersheds (TIA > 45%). Figure 7 also shows the relationship between urbanization and the EMC of total zinc (TZn). Total phosphorus and total suspended solids showed similar relationships. Zinc and lead in the sediment also showed a relationship with urbanization, again with the highest concentrations occurring in the most developed basins, although all were still below sediment-quality guidelines. As with other recent studies (Bannerman et al., 1993; Pitt et al., 1995), these findings indicate that the chemical water quality of urban streams is generally not significantly degraded at low impervious levels, but it may become a more important factor in streams draining highly urbanized watersheds.

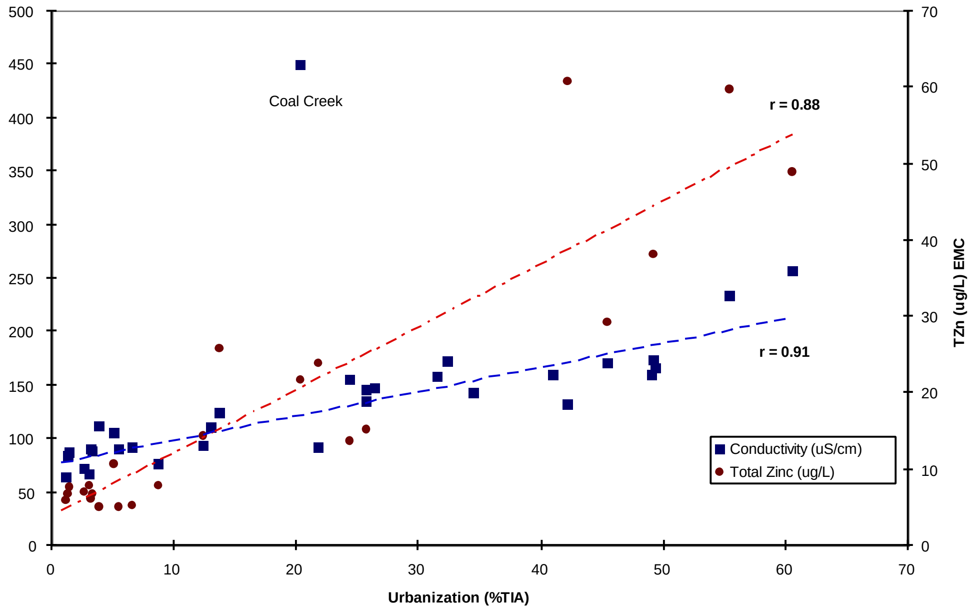

Figure 7. Baseflow conductivity and storm event mean concentration (EMC) of total zinc (TZn) compared with watershed urbanization (%TIA) in Puget Sound lowland (PSL) streams.

Instream Salmonid Habitat Characteristics

Large woody debris (LWD) is a ubiquitous component in streams of the PNW. No other structural component is as important to salmonid habitat, especially for juvenile coho (Bisson et al., 1988). LWD performs several critical functions in forested lowland streams, including dissipation of flow energy, protection of streambanks, stabilization of streambeds, storage of sediment, and providing instream cover and habitat diversity (Bisson et al., 1987; Masser et al., 1988; Gregory et al., 1991). Although the influence of LWD may change over time, both functionally and spatially, its overall importance to salmonid habitat is significant and persistent. Both the prevalence and quantity of LWD declined with increasing basin urbanization (Figure 8). At the same time, measures of salmonid rearing habitat, including percentage of pool area, pool size, and pool frequency, were strongly linked to the quantity and quality of LWD in PSL streams. While LWD quantity and quality were negatively affected by urbanization, even many of the natural, undeveloped streams lacked LWD (especially very large LWD). This deficit appears to be a residual effect of historic timber-harvest and “stream-cleaning” activities. Nevertheless, with few exceptions (habitat restoration sites), high quantities of LWD occurred only in streams draining undeveloped basins (TIA < 5%). It appears that stream restoration in the PSL should include enhancement of instream LWD, including addressing the requirement for long-term recruitment of LWD.

An intact and mature riparian zone is the key to maintaining instream LWD (Masser et al., 1988; Gregory et al., 1991). The lack of functional quantities of LWD in PSL streams was significantly influenced by the loss of riparian integrity (Figure 9). In general, except for restoration sites, higher quantities of LWD were found only in stream segments with intact upstream riparian corridors. In addition, LWD quality was strongly influenced by riparian integrity. Very large, stable pieces of LWD (greater than 0.5 m in diameter) were found only in stream segments surrounded by mature, coniferous riparian forests. This natural LWD historically provided stable, long-lasting instream structure for salmonid habitat and flow mitigation (Masser et al., 1988).

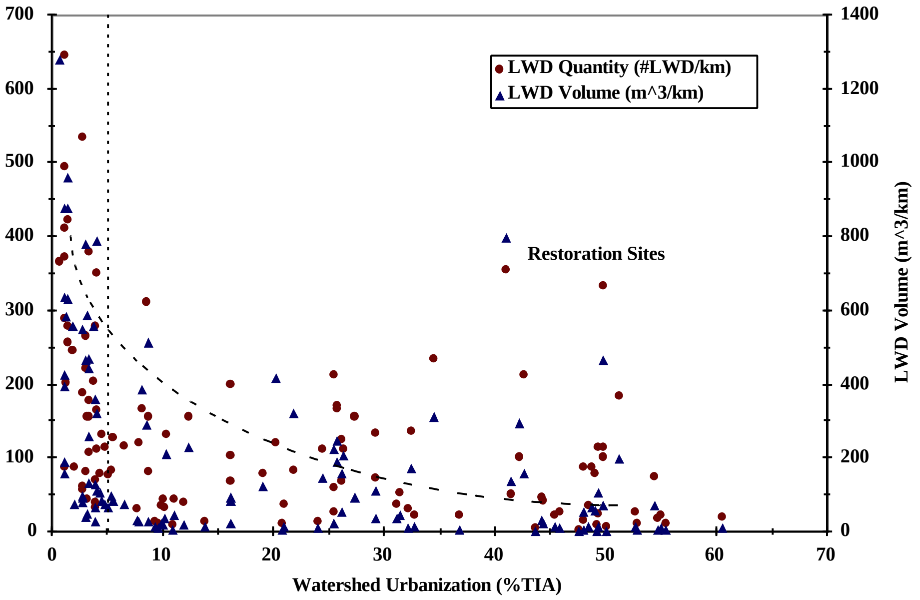

Figure 8. LWD quantity and watershed urbanization (%TIA) in Puget Sound lowland (PSL) streams.

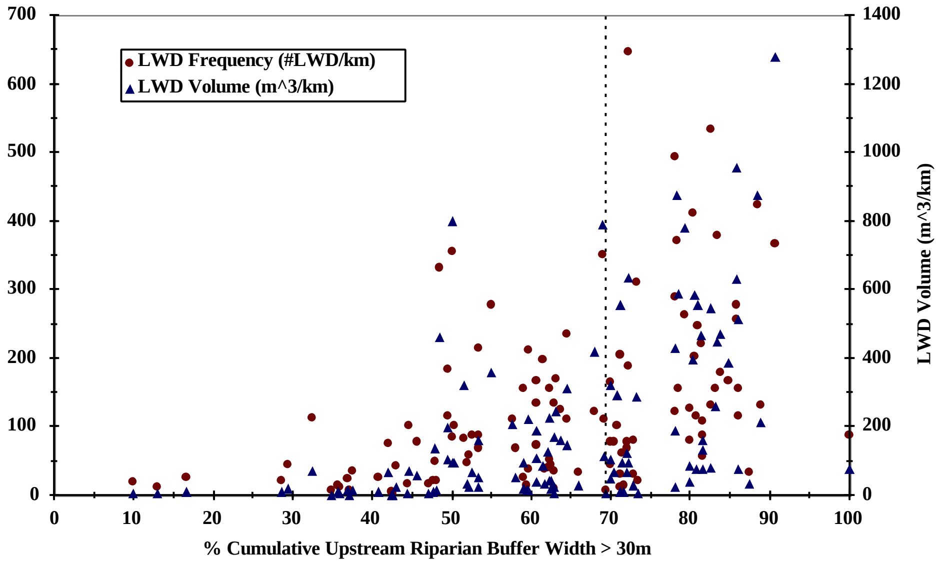

Figure 9. LWD quantity and riparian integrity in Puget Sound lowland (PSL) streams.

The stream bottom substratum is critical habitat for salmonid egg incubation and embryo development, as well as being habitat for benthic macroinvertebrates. Streambed quality can be degraded by deposition of fine sediment, by streambed instability due to high flows, or both. Although the redistribution of streambed particles is a natural process in gravel-bed streams, excessive scour and aggradation often result from excessive flows. Streambed stability was monitored using bead-type scour monitors (Figure 10) installed in salmonid spawning riffles in selected reaches (Nawa and Frissell, 1993).

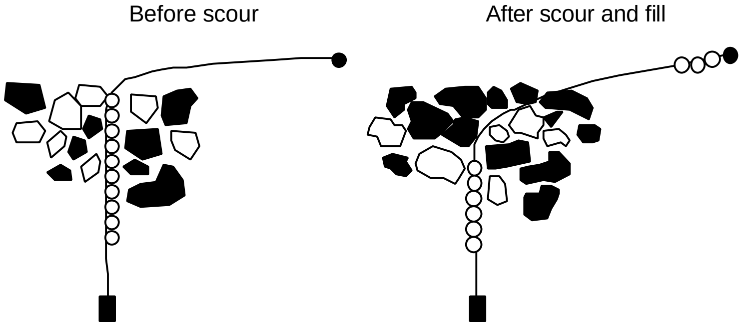

Figure 10. Sliding-bead type scour monitors used to monitor streambed instability.

As would be expected, larger scour and/or fill events usually resulted from larger storms and the resultant higher flows. The available stream power and basal shear stress may be the most significant factors affecting the potential for streambed instability. Stream power is proportional to discharge and slope. Since flows tend to increase with urbanization, it would generally be expected that stream power would increase as urbanization does, all else being equal. Cooper (1996) found this to be the case for the PSL study streams. Shear stress is dependent on slope, flow velocity, and streambed roughness. It is the critical basal shear stress that determines the onset of streambed particle motion and the magnitude of scour and/or aggradation. Because local slope and streambed roughness are highly variable, it is not surprising that scour and fill are also variable and that no significant relationship was noted between the 2-year stormflow to winter-baseflow ratio and any of the scour monitor measurements. This tends to emphasize the local nature of scour and aggradation events. Nevertheless, basin urbanization in PSL streams was found to have the potential to cause locally excessive scour and fill. Urban streams in the PSL with gradients greater than 2% and lacking in LWD were found to be more susceptible to scour than their undeveloped counterparts.

Streambank erosion was also far more common in PSL streams draining urbanized watersheds than in streams draining undeveloped watersheds. A survey protocol similar to that of Booth (1996) was used to evaluate all stream segments for streambank stability. Stream segments where >75% of the reach was classified as stable were given a score of 4. Between 50% and 75% was scored as 3, 25–50% as 2, and <25% as 1. Artificial streambank protection (riprap) was considered a sign of bank instability and scored as 1. Only two undeveloped, reference stream segments (TIA < 5%) had a stability rating of less than 3. In the 5–10% range, the streambank ratings were generally 3 or 4. Between 10 and 30%, there was a fairly even mixture of streambank conditions from stable and natural to highly eroded or artificially “protected.” Above a TIA of 30%, no segments had a streambank stability rating of 4, and very few had a rating of 3. The latter were found only in segments with intact and wide riparian corridors. Artificial streambank protection (riprap) was a common feature of all highly urbanized streams (TIA > 45%). Overall, the streambank stability rating was inversely correlated with cumulative development (%TIA) upstream and even more closely correlated with development within the segment itself, perhaps reflecting the local effects of construction and other human activities. Streambank stability was also influenced by the condition of the riparian vegetation surrounding the stream. In this study, the streambank stability rating was strongly related to the width of the riparian buffer zone and inversely related to the number of breaks in the riparian corridor. While not completely responsible for the level of streambank erosion, basin urbanization and loss of riparian vegetation contribute to the instability of streambanks. Besides vegetative cover, other stream corridor characteristics, such as soil type and valley hillslope gradient, also contribute to the stability of the streambanks.

Fine sediment sampling (using the McNeil method) indicated that urbanization can also degrade streambed habitat. The levels of fine sediment (%fines) were related to upstream urban development, but the variability, even in undeveloped reaches, was quite high (Wydzga, 1997). Nevertheless, fines did not exceed 15% until TIA exceeded 20%. In the highly urbanized basins (TIA > 45%), the fine sediment was consistently > 20% except in higher gradient reaches, where the sediment was presumably flushed by high stormflows.

The intragravel dissolved oxygen (IGDO) was also monitored as an integrative measure of the deleterious effect of fine sediment on salmonid incubating habitat. IGDO monitors were installed in artificial salmonid redds and monitored throughout the coho incubation period (Figure 11). A significant impact of fine sediment on salmonids is the degradation of spawning and incubating habitat (Chapman, 1988). The incubation period represents a critical and sensitive phase of the salmonid life cycle. During this period, the typical mortality rate in natural streams can be quite high (>75%). A high percentage of fine sediment can effectively clog the interstitial spaces of the substrata and reduce water flow to the intragravel region. This can reduce the levels of IGDO and build up metabolic wastes, leading to even higher mortality. In extreme situations, sediment can form a barrier to alevin emergence, resulting in entombment and death. Elevated fine sediment levels can also have various sublethal effects on developing salmonids which may reduce the odds of survival in later life stages (Steward, 1983). While low IGDO levels are typically associated with fine sediment intrusion into the salmonid redd, local conditions can have a strong influence on intragravel conditions as well as the distribution of fine sediment (Chapman, 1988). Spawning salmonids themselves can also reduce the fine sediment content of the substrata, at least temporarily.

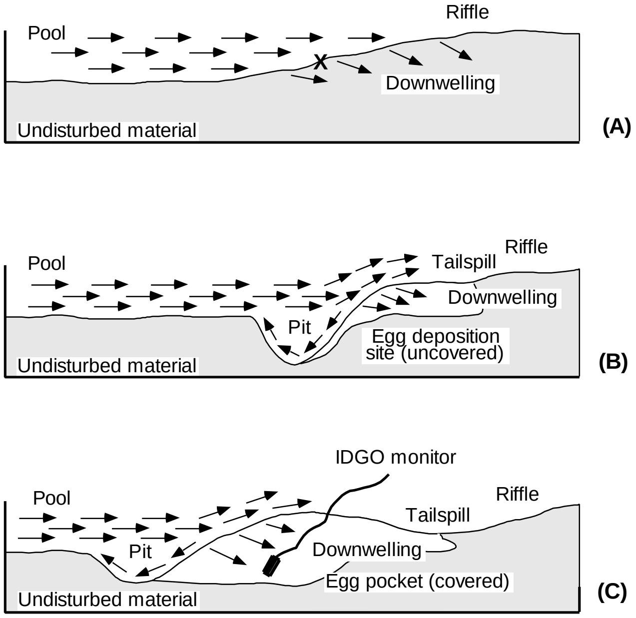

Figure 11. Architecture of a typical salmonid redd showing position of intragravel dissolved oxygen (IGDO) monitor. (a) Streambed topography near pool tailout. Likely spawning area is marked with an X. (b) Redd construction creates a low-flow zone, facilitating egg deposition and fertilization (fine sediment is flushed from pocket). (c) egg pocket covered by upstream digging and down-welling flow maximized by redd topography. Induced flow flushes sediment, provides oxygenated surface water to developing embryos, and removes metabolic wastes. (modified from Bjorn and Reiser, 1991)

Coincident measurements of instream DO and IGDO allowed calculation of a IGDO/DO interchange ratio (Figure 12). In all but one case, the mean interchange ratio was > 80% in the undeveloped reaches (TIA < 5%). As basin development (%TIA) increased above 10%, there was a great majority of the reaches in which the mean interchange ratio was well below 80% (as low as 30%). While these DO levels are not lethal, low IGDO levels during embryo development can reduce survival to emergence (Chapman, 1988). Several urbanized stream segments had unexpectedly high (>80%) IGDO concentrations (see Figure 12). All of these segments were associated with intact riparian corridors and upstream riparian wetlands. Generally, these reaches also had stable streambanks and adequate levels of instream LWD.

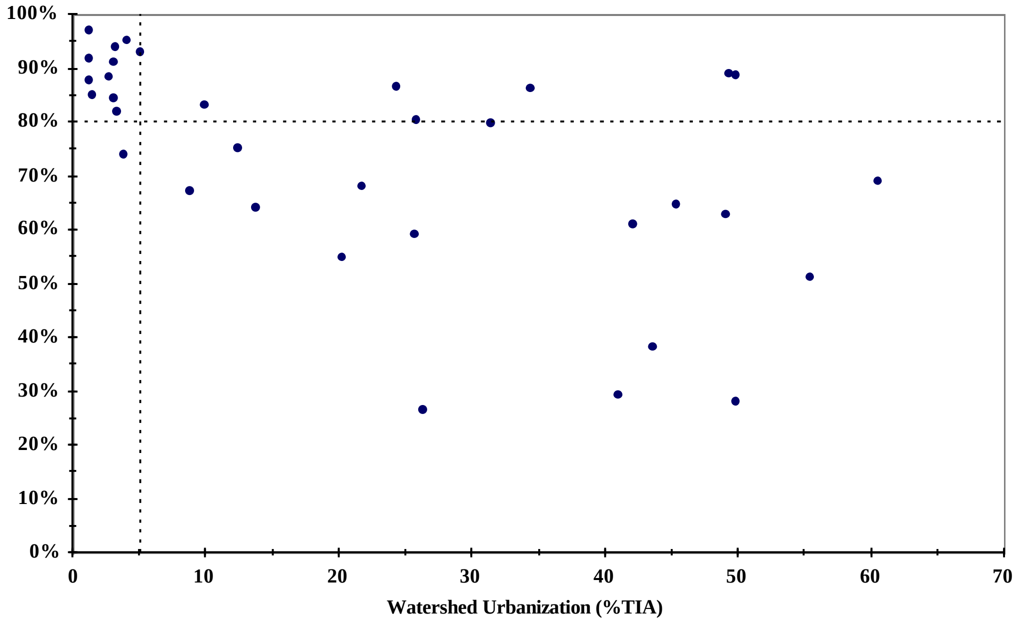

Figure 12. Relationship between urbanization (%TIA) and the ratio between mean intragravel dissolved oxygen (IGDO) and instream dissolved oxygen (DO) in Puget Sound lowland (PSL) streams.

Coho salmon rely heavily on small lowland streams and associated off-channel wetland areas during their rearing phase (Bisson et al., 1988). They are the only species of salmon that overwinters in the small streams of the PSL. Cutthroat trout are commonly found in almost all small streams in the PNW. Cutthroat and coho are sympatric in many small streams in the PNW and as such are potential competitors (adult cutthroat also prey on juvenile coho). In general, habitat, rather than food, is the limiting resource for most salmonids in the PNW region (Groot and Margolis, 1991). In urban streams of the PSL, rearing habitat appears to be the limiting factor. This study found that in all but the most pristine lowland streams (TIA < 5%) significantly less than 50% of the stream habitat area was pools (Figure 13). Even in these "reference" streams, pool habitat was generally below the "target" level of 50% recommended (Peterson et al., 1992). This is presumably due to the effects of past land-use practices (timber harvest and agriculture) and lack of instream LWD (see Figures 8 and 9). In addition, the fraction of cover on pools decreased in proportion to sub-basin development. The most urbanized streams had significantly less pool habitat (on average, less than half) than that found in reference streams (Figure 13a). Coho rear primarily in pools with high habitat complexity, with abundant cover, and where LWD is the main structural component (Bisson et al., 1988). The cumulative effects of human activity in the watershed, including the loss of riparian forest area and reduced instream LWD, significantly reduced pool area, pool diversity, and pool quality. As a result, instream habitat complexity in urban streams is far below that necessary to support a diverse and abundant salmonid community.

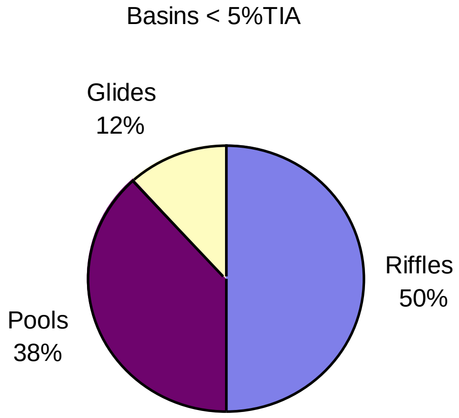

Figure 13a. Habitat unit distribution (TIA < 5%).

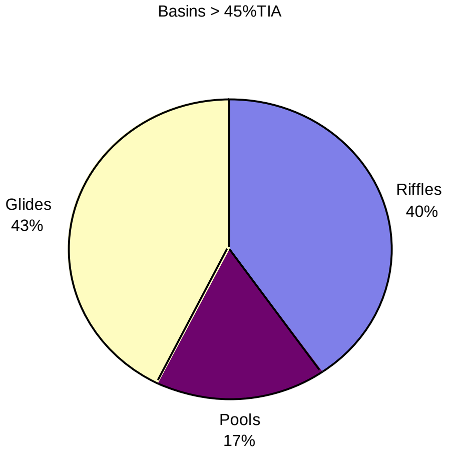

Figure 13b. Habitat unit distribution (TIA > 45%).

Biological Integrity

The multi-metric benthic index of biotic integrity (B-IBI) developed by Kleindl (1995) and Karr (1991) was used as a measure of the biological condition of the benthic macroinvertebrate community in PSL streams. The abundance ratio of juvenile coho salmon to cutthroat trout (Lucchetti and Fuerstenberg, 1993) was used as a measure of salmonid community integrity. Figure 14 shows a direct relationship between urbanization (%TIA) and biological integrity, using both measures. Only undeveloped reaches (TIA < 5%) exhibited an B-IBI of 32 or greater (45 is the maximum possible score). There also appears to be a rapid decline in biological integrity with the onset of urbanization. At the same time, it appears unlikely that streams draining highly urbanized sub-basins (TIA > 45%) could maintain a B-IBI greater than 15 (the minimum B-IBI is 9). B-IBI scores between 25 and 32 were associated with reaches with a TIA < 10%, with eight notable exceptions (see Figure 14). These eight reaches had sub-basin TIA values in the 25–35% (suburban) range, and yet each had a much higher biological integrity than other streams at this level of development. All eight had a large upstream fraction of intact riparian wetlands and all but one had a large upstream fraction of wide riparian buffer (>70% of the stream corridor with a buffer width > 30 m). These observations indicate that maintenance of a wide, natural riparian corridor may mitigate some of the effects of watershed urbanization.

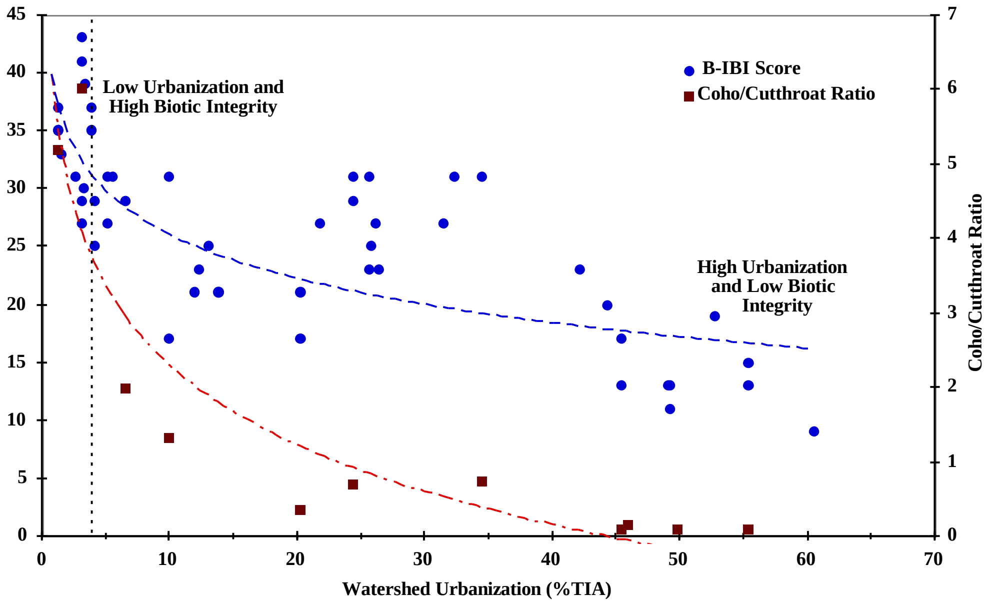

Figure 14. Relationship between watershed urbanization (%TIA) and biological integrity in Puget Sound lowland (PSL) streams. The benthic index of biotic integrity (B-IBI) and the abundance ratio of juvenile coho salmon to cutthroat trout were used as indices of biological integrity.

Urbanization also appears to alter the relationship between juvenile coho salmon and cutthroat trout. In this study, coho tended to dominate in undeveloped (TIA < 5%) streams, whereas cutthroat were more tolerant of conditions found in urbanized streams. Figure 14 shows the coho-to-cutthroat abundance ratio in those PSL study streams (11) where data were available for the period of the study. Natural coho dominance (cutthroat:coho ratio > 2) was seen only at very low watershed development levels (TIA < 5%). It is significant that both salmonid and macroinvertebrate data indicate a substantial loss of biological integrity at a very low level of urbanization. These results confirmed the findings of earlier regional studies (Perkins, 1982; Steward, 1983; Scott et al., 1986; Lucchetti and Fuerstenberg, 1993).

Given that relationships were identified between basin development and both instream habitat characteristics and biological integrity, it is reasonable to hypothesize that similar direct relationships exist between physical habitat and biological integrity. As a general rule, instream habitat (both quantity and quality) correlated well with biological integrity. For example, measures of spawning and rearing habitat quality were closely related to the coho:cutthroat ratio, and measures of streambed quality (benthic macroinvertebrates) were closely related to the B-IB. Chemical water quality may also influence aquatic biota at higher levels of watershed urbanization.

In addition to the quantitative habitat measures, a multi-metric Qualitative Habitat Index (QHI) was also developed for PSL streams. This index assigns scores of poor (1), fair (2), good (3), and excellent (4) to each of 15 habitat-related metrics, then sums all 15 metrics for a final reach-level score (the minimum score is 15 and maximum is 60). The QHI is similar in design to that used in Ohio (Rankin, 1989) and as part of the US EPA Rapid Bioassessment Protocol (Plafkin et al., 1989). As was expected, biological integrity was directly proportional to instream habitat quality (Figure 15). Coho dominance is consistent with a B-IBI > 33 and a QHI > 47, conditions found only in natural (TIA < 5%), undeveloped streams. These results were consistent with the findings of a similar study in Delaware (Maxted et al., 1994). The QHI has the advantage of being simpler (less costly) than more quantitative survey protocols, but may not meet the often rigorous (quantitative) requirements of resource managers. However, as a screening tool, it certainly has merit.

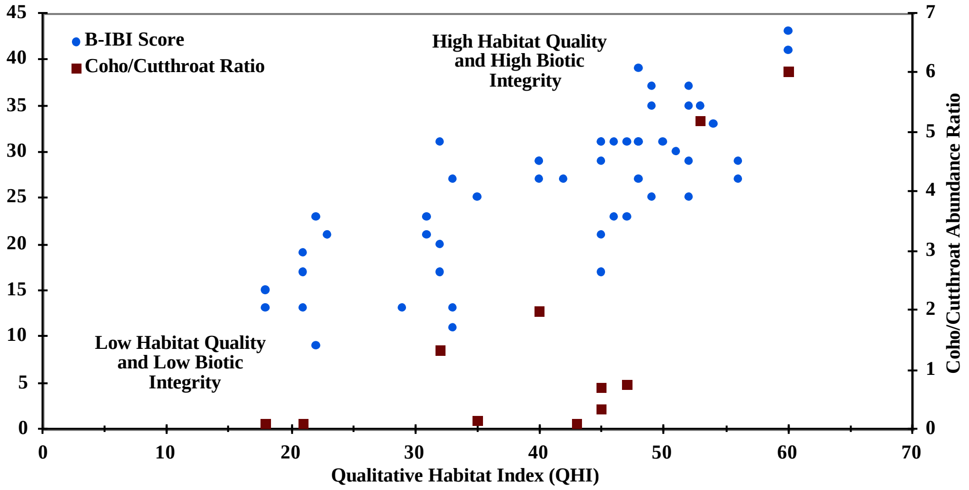

Figure 15: Relationship between instream habitat quality and biotic integrity in Puget Sound lowland (PSL) streams. The benthic index of biotic integrity (B-IBI) and the ratio of juvenile coho salmon to cutthroat trout are used as indices of biological integrity.

A major finding of this study was that wide, continuous, and mature-forested riparian corridors appear to be effective in mitigating at least some of the cumulative effects of adjacent development. Figure 16 illustrates how the combination of riparian buffer condition and basin imperviousness affects biological integrity, as measured by the B-IBI. These observations suggest a set of possible stream quality zones similar to those proposed by Steedman (1988). Excellent (natural) stream quality requires a low level of watershed development and a substantial amount of intact, high-quality riparian corridor. If a “good” or “fair” stream quality is acceptable, then greater development may be possible, with an increasing amount of protected riparian buffer being required. Poor stream quality is almost guaranteed in highly urbanized watersheds or where riparian corridors are negatively impacted by human activities such as development, timber harvest, grazing, or agriculture. Because of the mixture of historical development practices and resource protection strategies included in the study area, it was difficult to make an exact judgment as to how much riparian corridor is appropriate for each specific development scenario. More intensive research is needed in this area.

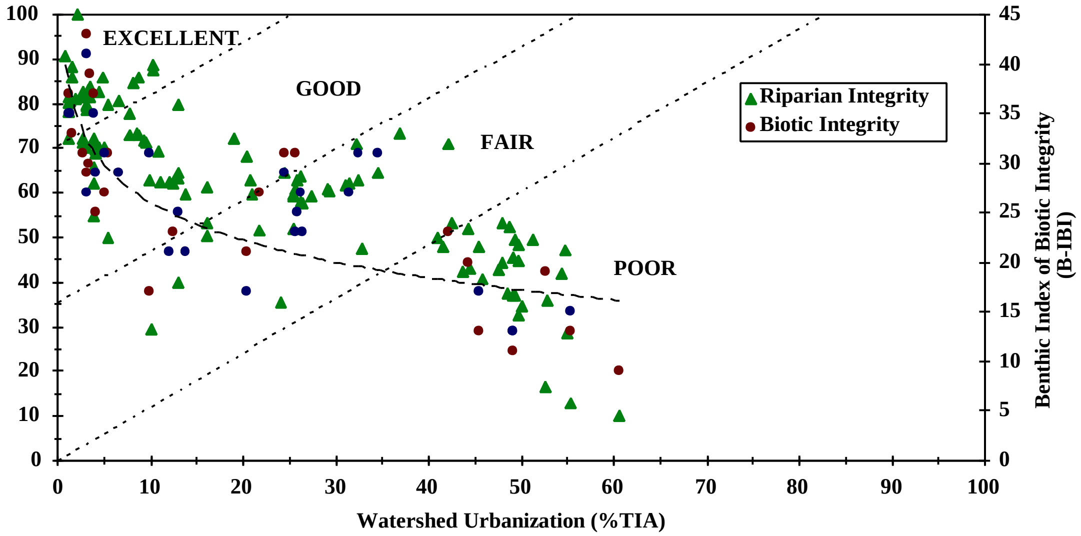

Figure 16. Relationship between basin development, riparian buffer width, and biological integrity in PSL streams

SUMMARY

Results of the PSL stream study have shown that the physical, chemical, and biological characteristics of streams change with increasing urbanization in a continuous rather than a threshold fashion. Although the patterns of change differed among the attributes studied and were more strongly evident for some than for others, physical and biological measures generally changed most rapidly during the initial phase of the urbanization process as TIA rose above 5–10%. As urbanization progressed, the rate of degradation of habitat and biologic integrity usually became more constant. There was also direct evidence that alteration of the watershed hydrologic regime was the leading cause for the overall changes observed in instream habitat conditions.

Chemical water quality constituents and concentrations of metals in sediments did not follow this pattern. These variables changed little over the urbanization gradient until imperviousness (%TIA) approached 40%. Even then water column concentrations did not surpass aquatic life criteria, and sediment concentrations remained far below freshwater sediment guidelines. As urbanization (%TIA) increases above the 50% level, the point where most pollutant concentrations rise rapidly, it is likely that the role of water and sediment chemical water quality constituents becomes more important biologically.

It is also apparent that, for almost all PSL streams, the quantity and quality of large woody debris must be restored for natural instream habitat diversity and complexity to be realized. Of course, prior to undertaking any habitat enhancement or rehabilitation efforts, the basin hydrologic regime must be restored to nearly natural conditions. Results suggest that resource managers should concentrate on preserving high-quality stream systems through land-use controls, maintenance of riparian buffers, and protection of critical habitat. Enhancement and mitigation efforts should be focused on watersheds where ecological function is impaired but not entirely lost.

Alterations in the biological community of urban streams are clearly a function of many variables representing conditions in both the immediate and more remote environment. In addition to urbanization level, a key determinant of biological integrity appears to be the quantity and quality of the riparian zone available to buffer the stream ecosystem, in some measure, from negative influences in the watershed (see Figure 16). Instream habitat conditions also had a significant influence on instream biota. Streambed quality, including fine sediment content and streambed stability, clearly affected the benthic macroinvertebrate community (as measured by the B-IBI). The composition of the salmonid community was also influenced by a variety of instream physio-chemical attributes. In the PSL region, management of all streams for coho (and other sensitive salmonid species) may not be feasible. Management for cutthroat trout may be a more viable alternative for streams draining more highly urbanized watersheds. The apparent link shown here between watershed, riparian zone, instream habitat, and biota supports management of aquatic systems on a watershed scale.

This research indicates that there is a set of conditions that, though not individually sufficient, are necessary to maintain a high level of stream quality or ecological integrity (physical, chemical, and biological). If maintenance of that high level is the goal, then this set of conditions constitutes the standards that must be achieved if the goal is to be met. For the PSL streams, imperviousness must be severely limited, unless mitigated by extensive protection of the riparian corridor and BMPs. Downstream changes to both the form and function of stream systems appear to be inevitable unless limits are placed on the extent of urban development. Stream ecosystems are not governed by a set of absolute parameters but are dynamic and complex systems. We cannot "manage" streams but instead should work more as "stewards" to maintain naturally high stream quality. Preservation and protection of high-quality resources should be a priority. Engineering solutions are useful in some situations in urban streams, but in most cases they cannot fully mitigate the effects of development. Rehabilitation and enhancement of aquatic resources will almost certainly be required in all but the most pristine watersheds. In order to support natural levels of stream quality, the following recommendations are proposed.

- Reduce watershed imperviousness, especially targeting transportation-related surfaces and compacted pervious areas.

- Preserve at least 50% of the total watershed surface area as natural forest cover.

- Maintain an urbanized stream system drainage density that is within 25% of pre-development conditions (i.e., an urban/natural DD ratio < 1.25).

- Continuously monitor streamflow and maintain 2-year stormflow/baseflow discharge ratio of much less than 20.

- Allow no stormwater to drain directly into a stream without first being treated by quality and quantity control facilities.

- Replace culverted road crossings with bridges or by arched culverts with natural streambed material.

- Retrofit existing BMPs or replace them with regional (sub-basin) stormwater control facilities with the goal of restoring the natural hydrologic regime.

- Limit stream crossings by roads or utility lines to less than two per kilometer of stream length and strive to maintain a nearly continuous riparian corridor.

- Ensure that at least 70% of the riparian corridor has a minimum buffer width of 30 m and utilize wider (100-m) buffers around more sensitive or valuable resource areas.

- Limit encroachment of the riparian buffer zone through education and enforcement (< 10% of the riparian corridor should be allowed to have a buffer width of < 10 m).

- Actively manage the riparian zone to ensure a long-range goal of maintaining at least 60% of the corridor as mature, coniferous forest.

- Allow no development in the active (100-year) floodplain area of streams. Allow the stream channel freedom of movement within the floodplain area.

- Protect and enhance headwater wetlands and off-channel riparian wetland areas as natural stormwater storage areas and valuable aquatic habitat resources (buffers).

- Adopt a set of regionally specific stream assessment protocols including standardized biological sampling (e.g., B-IBI).

- Under low-to-moderate basin development, use chemical water quality monitoring sparingly, i.e., only if a chemical pollutant is suspected or in situations where biological monitoring indicates a problem. For highly urbanized streams, sampling should be more frequent but should still be focused on specific constituents of concern.

- Tailor monitoring of instream physical conditions to the specific situation; based on objectives. Salmonid habitat surveys should include a measure of rearing habitat (LWD and/or pools) and a measure of spawning/incubating habitat (%fines and/or IGDO). In addition, standard channel morphological characteristics (pebble count, and streambank condition) should be measured. Scour monitoring should be used to evaluate local streambed stability in association with specific development activity.

The complexity and diversity of salmonid life cycles and stream communities, along with our limited understanding of them, should engender caution in proposing any simple solutions to reverse the cumulative effects of urbanization in streams of the PSL region.

> **"Many of the things that must be done are little things - small things each citizen can do...things little in themselves, but vital, urgent, and far-reaching in cumulative results. Therefore, the matters here discussed are not to be dismissed lightly as the concerns of scientists, engineers, and government alone. Every citizen must understand the problems and play a part in the solution"**
>
> **Person, 1935**

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ARE WILD SALMON RUNS SUSTAINABLE IN REHABILITATED URBAN STREAMS?

By: Derek B. Booth

INTRODUCTION

Urban streams are degraded streams; this much is common knowledge. Society is eager to "rehabilitate" these streams, but funds are perennially limited and examples of failed efforts are commonplace. We need a framework for evaluating prospective rehabilitation candidates, for recommending realistic rehabilitation objectives, and for guiding the tangible design of rehabilitation projects that will achieve their desired functions in the real-world urban and suburban landscape. We should approach this problem with inspiring goals but *not* with wishful thinking, particularly if we actually intend to accomplish something. Instead, we should build from a systematic foundation of understanding the critical processes by which watershed urbanization affects physical and biological stream-channel functions.

Urban development imposes a variety of watershed changes that profoundly affect runoff processes and the downstream surface-water aquatic system. Attention is generally given to *channel changes*: the stream channel itself is the object of interest and also, typically, the focus of any subsequent restoration or rehabilitation efforts. Yet that stream channel, commonly draining up to many square kilometers, is the product of its upland watershed. The net effect of *upland changes*, occurring across the land surface of the contributing headwater catchments, is at least as important in determining overall stream function, degradation, and rehabilitation potential. The widespread failure to recognize these watershed interconnections, or the acknowledgment of those interconnections but the unwillingness to let that understanding guide choices for realistic rehabilitation goals or strategies, explains much of the present sorry state of salmonid habitat in the urban and urbanizing streams of the Pacific Northwest.

DEVELOPMENT-INDUCED UPLAND CHANGES

Modifications of the land surface during urbanization produce changes in both the type and the magnitude of runoff processes. These changes result from vegetation clearing, soil compaction, ditching and draining, and finally covering the land surface with impervious roofs and roads. The infiltration capacity of these covered areas is lowered to zero, and much of the remaining soil-covered area is trampled to a near-impervious state. Compacted, stripped, or paved-over soil also has lower storage volumes, and so even if precipitation can infiltrate, the soil reaches surface saturation more rapidly and more frequently. Thus rapid and voluminous *overland flow* is introduced into areas that formerly generated runoff only by much slower and attenuated subsurface flow paths.

Besides changing the hydrologic flow regime, urbanization affects other elements of the drainage system. Gutters, drains, and storm sewers are laid in the urbanized area to convey runoff rapidly to stream channels. Natural channels are often straightened, deepened, or lined with concrete to make them hydraulically smoother. Each of these changes increases the efficiency of the channel, transmitting the flood wave downstream faster and with less retardation by the channel. In total, direct measurements and hydrologic simulation models demonstrate several related consequences: for any given intensity and duration of rainfall the peak discharge is greater (by factors of 2 to 5), the duration of any given flow magnitude is longer (by factors of 5 to 10), and the frequency with which sediment-transporting and habitat-disturbing flows move down the channel network is increased dramatically (by factors of 10 or more).

Changes in upland runoff processes, particularly from a predominantly *subsurface* flow regime to a predominantly *surface* flow regime, alter not only the magnitude of discharges but also the delivery of sediment to the stream network. With overland flow, fine sediment is moved into channels throughout the year; when coupled with land-cover changes, the sediment load can increase by many orders of magnitude and the predominant grain-size distribution can shift to much finer fractions. Such increases in the delivery of fine sediments significantly alters the sediment size distribution of gravel bed streams.

Urban development not only increases rates of water and sediment delivery but also encroaches on the riparian corridor. From clearing of streamside vegetation less wood enters the channel, depriving the stream of stabilizing elements that help dissipate flow energy and usually (although not always) help protect the bed and banks from erosion. Deep-rooted bank vegetation is replaced, if at all, by shallow-rooted grasses or ornamental plants that provide little resistance to channel widening. Furthermore, the overhead canopy of a stream is lost, eliminating the shade that controls temperature and supplies leaf litter that enters the aquatic food chain.

At the end of this causal chain of upland, riparian, and channel changes lies the degradation of in-stream biological function that so often motivates rehabilitation efforts. In the Pacific Northwest, many of these efforts are focused on enhancing populations of anadromous salmon in lowland streams. These fish depend on particular combinations of water and sediment fluxes to maintain favorable channel conditions. Because land-use change in a watershed alters those fluxes, the resulting flow regime and channel configuration no longer tend to favor salmonids. An additional consequences is that rehabilitation efforts that address only the in-stream *symptoms* of these watershed changes are unlikely to succeed.

TOWARDS A WATERSHED-LEVEL, PROCESS-BASED APPROACH

Despite the inescapable connection between the stream channel and its contributing watershed, stream-channel rehabilitation has traditionally been conducted in near-isolation from the surrounding landscape: channels have a particular set of desired physical features (the channel *structure*) which are presumed to correlate precisely with the desired channel *functions:* if that structure is "deficient," it must be "fixed." A voluminous literature of channel-assessment techniques has been developed over the last two decades, determining any "deficiencies" in a given stream environment by comparison to some predetermined standard of acceptable channel structure. The implicit (but fundamental) assumption is normally made that the desired physical and biological *functions* always follow from the correct physical structure, regardless of whether that structure was achieved as the outcome of intact upland processes operating across the contributing watershed or as a consequence of site-specific application of earthmoving equipment and replanted vegetation.

As rehabilitation efforts have been applied to more profoundly disturbed areas, however, unintended consequences of this approach have become manifest. Unrealistic promises are made, large sums of limited resources are spent on projects that achieve their immediate structural objectives (and these only briefly) but which subsequently fail to meet biological goals, multiple projects with less ambitious individual goals but potentially greater aggregate benefit are ignored, and the overall quality and health of a region's waters decline in a seemingly inexorable downward spiral. The underlying reason is simple—severing the behavior of a stream network from its geomorphic context eliminates our ability to understand how the channel currently functions, how channel form and channel functions relate to each other, and how those functions may change following human intervention. Many of the critical changes underlying the loss of physical and biological functions are occurring on the *land surface* of headwater catchments; their effects will never be reversed by thinking only of the observed degradation in a downstream channel.

In addition to these physical and biological issues, there are social realities. Physical and biological changes in progressively more suburban and urban environments also are expressed by different categories of landscape settings: from the fringes of outer suburbia, in which flowing water, naturally changing stream banks, and woody vegetation are visible; to the most urban, in which little or no plant material or natural channels are visible. As the frequency, magnitude, and duration of runoff increase, the stream channel usually appears increasingly more derelict with mature trees cleared and channels straightened into ditches and canals overgrown by invasive vines and brambles. As a riparian corridor itself becomes more and more derelict, the adjacent upland landscape, especially in suburban areas, becomes more and more carefully tended. Homeowners plant lawns, a few trees and flowers are planted at shopping centers, and open spaces become groomed play fields or golf courses. The juxtaposition of a remnant "natural" corridor within a manicured, human-dominated landscape is a sharp visual contrast.

The general public often values a "derelict but natural" landscape as a reminder of the large natural landscape beyond the urban fringe. However, people will begin to "care for" these landscape by cleaning out woody debris and other desirable elements or by fashioning homemade retaining walls to stabilize eroding banks. In other words, while people generally *like* the idea of a stream nearby, they more likely want its appearance to fit into their neighborhood landscape—to look more manicured than scruffy. When public agencies attempt to restore degraded channels they either complete the manicuring process, with smoothed banks having little if any rehabilitation value, or they build more biologically functional measures that seem unkempt, scruffy, and even more derelict to the nearby homeowner than the original degraded site.

Thus any approach to stream rehabilitation, and the rebuilding of salmonid habitat in urban settings, must acknowledge both the complex dependencies of channel response on watershed land use and the social environment in which rehabilitation actions must be taken:

- What are the landscape processes that are critical in determining channel patterns?
- What are the channel processes that are critical in determining ecological function?
- How does urbanization affects the rate, the magnitude, the frequency, and the spatial distribution of those processes?
- What are the changes in physical patterns that result from urbanization?
- What are the biological, and social, implications of those changes?
- To what degree can we successfully reverse their undesired consequences, and under what circumstances will those actions be supported by the neighboring population?

Rehabilitation approaches will be most successful if they tackle the most important tasks out of those that are possible to address at all. In nearly all cases the single greatest change is one of *hydrology*—the disruption (and generally augmentation) of flows rolling off the surface of the watershed and entering the channel. Time and again, however, the willingness of governmental agencies or individual property owners to accept either the cost or the change in development patterns (or both) necessary to materially improve this condition has been insufficient. Until this political and economic reality changes, any other rehabilitation measures are likely to provide modest, incremental improvements at best; the most ambitious goals of returning self-sustaining salmon runs to urban streams will be wholly beyond reach.

If such “hydrologic rehabilitation” is not an option, other measures that yield measurable (though incomplete) benefits must be recognized. These include reducing sediment loads from hillslope sources and reestablishing "stability" of the overall channel grade, as the first steps to recover a stable form. But recognize that such restabilization is not equivalent to the dynamic stability of natural systems, and it has not occurred by the dynamic balance of flows, sediment, and bed resistance. Instead it arises simply from the imposition of rigid structures. This may necessary and appropriate in the urban environment, but the resulting channel form will not necessarily look "just like natural," and from a biologic point of view it certainly will not perform that way, either.

So what *should* be our set of “publicly inspiring yet technically realistic” goals for urban streams? Every community, every researcher, and probably every individual can and should have their own list; the following is simply my own:

1. **Do no harm**—Urban channels should not be toxic or lethal to temporary aquatic residents, and they should pose no significant barriers to migration into more hospitable areas farther upstream. Similarly, stream rehabilitation should not make matters worse.
2. **Address causes, not symptoms**—The most effective rehabilitation efforts must emphasize first the fundamental determining processes, such as hydrology, in disturbed watersheds. Only then can they target recreation of the structural in-channel features consistent with renewed processes, and *finally* reestablished biological activity. Taking this sequence out-of-order is very unlikely to produce biologically meaningful results (although it may support other valid community goals).
3. **Engage the public**—Urban channels, particularly in the Pacific Northwest, are one of the most visible and nearby manifestations of the natural environment. An interest to care for that environment, and a willingness to support the broader ecosystem, should arise from how those channels are managed and rehabilitated.
4. **Maintain stable channel grade**—Catastrophic channel failure, with attendant destruction of not only habitat quality but also aesthetic values and channel-bank stability, is most commonly associated with rapid channel incision. There is no adequate “cure” once this has occurred.
5. **Minimize sediment sources**—Geomorphically, this task should be secondary to that of minimizing flow increases, because increased overland flow is the greatest single source of increased sediment delivery, and because increased in-channel flow is the greatest single source of channel erosion (and thus new in-

channel sediment). Yet minimizing sediment is generally a far more tractable task than that of minimizing flows, and techniques are more readily and cheaply available to achieve relative success. Even the best results, however, will not produce a channel with a pre-development sediment flux.

6. **Enhance biological activity—**Regardless of whether self-sustaining wild salmon will ever repopulate the urban streams of the Pacific Northwest, *any* level of fish use, and the biological activity that surrounds that use, supports both ecological and community goals. It is not hypocritical to have to constantly restock "boutique" salmon runs in urban streams, because it brings direct aesthetic and educational values to the community. It is less credible, however, to imply that such measures are but a temporary step on the way to long-term biotic integrity. Without clear articulation of what is plausible, limited resources may be spent on what can *never* be achieved while more attainable objectives languish forever.

TRADITIONAL ALTERNATIVES: WILL MORE DETENTION WORK?

By: Douglas Beyerlein, P.E., and Joseph Brascher

QUESTION: Will More Detention Work?

ANSWER: No.

For the past 20 years local jurisdictions in the Puget Sound region have required stormwater detention facilities (ponds, tanks, and vaults) to be constructed to mitigate the impacts of development on our streams, rivers, and lakes. Standards were established to attempt to prevent runoff from development from increasing streamflows.

As hydrologists and engineers we participated in setting the standards, selecting the methodologies, and designing and building detention facilities. This was all for the purpose of protecting our aquatic systems while allowing development in our watersheds.

We have failed. With development has come increased winter flood flows, decreased summer low flows, and a general degradation of our stream systems.

We have failed because we are trying to replace the complex interactions of the hydrologic cycle with a pond. It can't be done. Table 1 shows why.

Table 1 shows where our average annual rainfall of 40.70 inches goes.

Table 1.	Surface Runoff (in)	Interflow (in)	Ground-water (in)	Evapotrans-piration (in)
Land Use				
Forest	0.09	8.46	13.40	18.79
Pasture	0.29	13.26	10.15	17.02
Lawn	0.61	16.72	8.89	14.48
Rural Residential (forest)	1.56	10.81	11.05	17.31
Rural Residential (pasture)	1.64	12.73	9.75	16.60
Suburban Residential	9.30	12.37	6.58	12.44
Multi-family Residential	16.66	8.69	4.62	10.72
Commercial	29.37	2.34	1.24	7.74
Impervious	34.05	0.00	0.00	6.64

In the natural forested environment almost half of our rainfall returns to the atmosphere via evapotranspiration. Evapotranspiration (ET) is the combined effect of evaporation of water from surfaces and transpiration of water from the soil by plants.

In the paved environment less than 20 percent of the rainfall becomes ET.

With development we have more water that becomes runoff. We have less natural storage for it because we are putting less water into the ground. It is this groundwater that supplies our streams with water during summer dry periods.

Instead we are increasing surface runoff, which is the water that gets to the streams the quickest. Interflow, the water that travels just below the surface, is not far behind. Together, surface runoff and interflow produce floods.

Stormwater detention is suppose to slow down the runoff from development and make it behave like natural runoff. It isn't working. And it can't work when you look at the numbers in Table 2.

Table 2.	Surface Runoff + Interflow (in)	SR+I Change from Forest (in)	Ground-water (in)	GW Change from Forest (in)
Land Use				
Forest	8.55	0.00	13.40	0.00
Pasture	13.55	5.00	10.15	-3.24
Lawn	17.32	8.77	8.89	-4.51
Rural Residential (forest)	12.37	3.82	11.05	-2.35
Rural Residential (pasture)	14.37	5.82	9.75	-3.65
Suburban Residential	21.67	13.12	6.58	-6.82
Multi-family Residential	25.35	16.80	4.62	-8.78
Commercial	31.71	23.15	1.24	-12.15
Impervious	34.05	25.49	0.00	-13.40

Just the act of cutting down trees and replacing them with pasture increases the bad runoff (surface runoff plus interflow) by 5 inches per year and decreases the good runoff (groundwater) by more than 3 inches. **No detention is required by government agencies.**

Replacing forest with lawn (residential sod) is worse. The bad runoff increases by almost 9 inches and the good runoff decreases by 4.5 inches. **Again, no detention is required by public agencies because no impervious area has been added.**

Detention is required once more than 5000 square feet of impervious area has been added to the development. But is it enough?

No.

In the Puget Sound region the Washington State Department of Ecology (DOE) has set the minimum standard for stormwater detention. The DOE Stormwater Management Manual requires that the runoff from new development (with more than 5000 square feet of impervious area) not exceed the 2-year and 10-year predevelopment floods. For a 100-acre development this produces the pond sizes shown in Table 3.

Table 3.	DOE Required Pond Size (acre-feet)	Actual Required Size (acre-feet)	Increase Needed (acre-feet)	Percent Increase
Land Use				
Forest	0.00	0.00	0.00	0
Pasture	0.00	5.16	5.16	--
Lawn	0.00	8.24	8.24	--
Rural Residential (forest)*	0.63	4.23	3.60	572%
Rural Residential (pasture)*	1.41	5.98	4.57	324%
Suburban Residential	2.85	13.45	10.60	372%
Multi-family Residential	6.88	18.99	12.11	176%
Commercial	10.88	29.59	18.71	172%
Impervious	11.86	33.92	22.06	186%

* assuming more than 5000 sq. feet of impervious area; otherwise, no pond is required.

The DOE ponds are too small.

Even if the ponds were sized to the actual required size (based on HSPF-generated runoff), mitigation based on the 2-year and the 10-year floods does not protect our streams.

Development with ponds increases the smaller flood flows and increases the length of time of flooding. This can be just as destructive to the streams and the salmon as the bigger floods. Controlling flow durations is the key to protecting them.

Flow duration is the percent of time that a particular size of flow is exceeded. For example, if a flow in a stream is greater than 1 cfs (cubic foot per second) for a total of 876 hours in a year then the flow duration for 1 cfs is 10 percent of the time (365 days times 24 hours equals 8760 hours in a year; 876/8760 equals 10%).

The annual flood (1.01-year flood) for 100 acres of forest is 1 cfs. Table 4 shows how often this flow is exceeded for each of the 100-acre developments.

Converting 100 acres of forest to suburban residential development (with a 13 acre-foot pond) still results in 1 cfs (the 1.01-year forest flood) occurring for an additional 549 hours (23 days) a year. The excess runoff has to go somewhere.

Table 4.	Percent of Time Flows Exceed 1 cfs	Number of Hours per Year	Increase from Forest (hours)	Percent Increase
Land Use				
Forest	2.1%	181	0	0
Pasture	4.6%	401	220	122%
Lawn	6.3%	549	368	204%
Rural Residential (forest)	4.8%	419	238	132%
Rural Residential (pasture)	4.8%	422	241	134%
Suburban Residential	8.3%	730	549	304%
Multi-family Residential	10.1%	887	706	391%
Commercial	13.6%	1194	1013	561%
Impervious	15.0%	1313	1132	627%

The numbers in Table 4 are based on requiring the "Actual Required Size" ponds. In addition, it is assumed that ponds are also required for pasture, lawn, and rural residential, regardless of the amount of impervious area (or lack of). In other words, the number of flood flow hours will still increase even if we build ponds for everything. That is because we still have too much of the bad runoff (see Table 2 again).

Conclusions

More detention won't work. What will?

Keep the forests. Streams need trees. Salmon need trees.

Live in tree houses.

Or.

Where we do have development we need to change bad runoff to good runoff. The only way to do this is to drink the water. In other words, take all of the bad runoff, clean it of pollutants and sediment, and put the water into the ground. In areas with till soils this will require drilling through the hardpan layer of cemented silt and clay underlying the top soil to get the water into the ground. In areas of high water table infiltration of runoff will not work and development should not be allowed.

Or say good-bye to the salmon.

Your choice.

RESULTS FROM FOREST HYDROLOGY STUDIES: IS THERE A LESSON FOR URBAN PLANNERS?

By: Susan Bolton and Anne Watts

ABSTRACT: People have been wondering about mountains and hence forests and hydrology for centuries. King Solomon wrote: *All of the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again.* This is essentially a 3000 year old statement describing the hydrologic cycle. The hydrologic cycle can be conceptualized and studied in a variety of ways from careful analysis of each physical process to a more wholistic view of the cycle consisting of a system of storage reservoirs. Studies on individual components have looked at interception, evapotranspiration, infiltration, overland flow, subsurface flow, groundwater and streamflow. There has been considerable research on identifying the impacts of forest land cover changes on streamflow. Research sites have included paired basins, long-term nested basin sites, plot studies or review and synthesis of other studies. This presentation will present basic information necessary for understanding how the hydrologic cycle works, where water is stored, and how streamflow is affected by forest removal. The emphasis will be on what has been learned by researchers studying the effects of timber harvest on forest hydrology. Analogies between forestry and urbanization will be drawn and estimates of the impacts of urbanization will be made. Many of the research papers on the effect of forest management activities on stream hydrology are reported as percent change in annual flow, peak flow or low flow. For urban planners, the change in inches of runoff and not percent may be a more useful unit. The area of emphasis will be the Pacific Northwest coastal forests and only hydrological impacts will be discussed. Keep in mind that land use changes also impact many other physical and ecological processes.

Years of hydrologic research have not resulted in an entirely consistent set of results for predicted impacts of forest harvest on streamflow. However, the majority of studies show increases in peak stream flows and volumes in basins with timber harvest. The increase in flow is most noticeable in small basins from average storm events. The period of record, climate variability and harvesting histories make it very difficult to draw strong conclusions about the effect of harvesting on low frequency, high magnitude storms, especially in large basins. Many urban developments take place in relatively small drainage basin so the analogy between forest studies and expected changes due to urbanization is appropriate.

In small basins, hillslope processes dominate storm runoff processes. Critical hillslope processes are infiltration, evapotranspiration, and soil moisture at the beginning of the storm Timber harvest impacts three main components of the hydrologic cycle. **(1)**Removal of the trees increases snow accumulation and decreases evapotranspiration which combine to increase soil moisture levels. Higher soil moisture leads to saturated subsurface/surface flow which increases the amount of water reaching the channel quickly.
(2) Removal of large woody debris from the stream channels and the lack of large, older trees for recruitment to the channel decreases pool formation (pond storage) and decreases flow resistance, which means less water can be stored in the channel and water moves through the channel faster. **(3)** Road building to access the timber harvest sites compacts the soil in the road pathway which decreases infiltration and increases surface runoff. The cut banks of the roads intercept subsurface flow and turn it into surface flow. The road cut also decreases the soil available for moisture storage. The ditches and culverts along the roads create new channels for overland flow. The effect of roads is to increase the drainage density and hence water delivery to the streams. Water in channels travels much faster than does water flowing through the soil. Each of these three activities push the hydrologic cycle towards faster runoff and greater storm runoff. The forest studies were designed to evaluate changes in streamflows due to total or partial timber harvest. Most studies show that clearcutting in small basins increases storm runoff, especially early fall storm runoffs and winter storm runoff.

Recovery does occur from the three impacts mentioned above when the land is kept in forest usage and trees are replanted. Evapotranspiration recovers in about 5 years as new vegetation pushes roots into the deeper soil layers. Canopy interception may take decades to recover as the trees need go through several stages to form a complex canopy structure. Large woody debris, unless placed by humans, takes at least 60-90 years to recover because trees have to grow, become large and fall over. Roads, even in forests, tend to be relatively permanent changes in the systems. Data are inconclusive as to whether recent attempts at road abandonment and removal are effective. History has shown that the old railroad grades have been colonized by alders on the west side of the Cascades but it does take decades for this to occur.

Table 1 shows differences in the various processes that affect the water balance in different vegetation/climate zones. Annual increases in water yield are important and harvest has been used to increase streamflow. Most planning is done for single precipitation events so it is necessary to see where water is stored in the system, how much water can be stored in different compartments and how long it is stored.

Table 1. Average Annual Water Balance (in inches) for West Coast Forests and Potential Increase in Yield due to Harvesting

Forest Type	Precipitation	Streamflow	Evapotranspiration	Potential Water Yield Increase
Douglas fir/ hemlock/redwood	75	45	30	15.0
Mixed conifers	44	22	22	4.5
True fir	60	36	24	6.0

The hydrologic cycle can be viewed as a system of six compartments with fluxes carrying mass and energy among the compartments.

- energy sphere (the sun)
- atmosphere (wind and precipitation)
- hydrosphere (streams, lakes and ground water)
- biosphere (vegetation)
- terrasphere (soil)
- cultural sphere (human activities)

The sun is the driving force behind the hydrologic cycle and provides the energy that melts snow, condenses water vapor, evaporates water, and drives weather systems. It also drives photosynthesis and respiration in plants that lead to water uptake from the soil by plants. The atmosphere, via weather patterns and global circulation, stores water as vapor and distributes moisture around the globe. The biosphere is the vegetation zone of the earth’s surface. On a global basis, the biosphere stores 17 times more water than the atmosphere. Water is stored on and in vegetation as interception or tissue water, respectively. The terrasphere is the soil covering the geologic substructure. Water moves through the soil by gravity except when it is responding to tension gradients exerted by plants and soil particles. Humans have little control over the sun or the weather, but we do alter storage in the hydrosphere, soil, and vegetation.

Water can be stored temporarily in soil depressions in response to a precipitation or runoff event. This water is ultimately either infiltrated or evaporated. Soil detention storage is soil water that drains via gravity and is not held in tension by soil particles. It is seldom held more than 24 hours. Detention storage is the difference in soil water between saturation and field capacity. Soil retention storage is water held by bonds between water molecules and soil particles and can only be extracted by plant roots. Some water is held so tightly by soil particles that it cannot be extracted by plant roots. Retention storage is the difference between field capacity and wilting point. Table 2 shows storage values for two common soil types in Puget Sound. Table 3 uses data from the literature to estimate the amount of water storage in different compartments. Evapotranspiration ranges from 0 to 0.2 inches per day depending on soil moisture availability, weather conditions and photosynthesis rates.

Table 2. Potential Water Storage in Soil (inches per foot of soil depth)

Soil moisture level	Silty clay loam	Sandy loam

Saturation (S)	6.3	5.2
Field capacity (F)	4.7	2.4
Wilting point (W)	2.7	1.4
Detention storage = S - F	1.6	2.8
Retention storage = F - W	2.0	1.0
Total potential soil storage	3.6	3.8

Table 3. How much water can a forest hold?

Trees (Douglas fir)	1 inch
Interception (canopy) - rain	0.01-0.7 inch
Interception (canopy) - snow	0.01-1 inch
Interception (litter) - rain	0.02-0.44 inches
Soil detention storage	sandy loam 1.6 -- Silty clay loam 2.8 (in/ft of soil)
Soil retention storage	sandy loam 2.0-- Silty clay loam 1.0 (in/ft of soil)

Many PNW precipitation events are low intensity and low volume. Intact forests with thick canopies and deep litter layers can prevent many precipitation events from reaching the soil at all. Water that is stored as canopy interception by the litter layer either evaporates and is lost from the storm event or it drips and moves slowly to the soil and infiltrates. Very little precipitation ends up as overland flow in mature, undisturbed forests. Overland flow occurs on compacted soil areas like trails and roads, in places where undecomposed leaves may bind and form a sheet for water to run over, and in areas where the soil is saturated and cannot store any more water.

Urbanization follows the same pattern as forest harvest in its effects: tree removal, channel cleaning and straightening, and road building. However, the changes tend to be permanent. Soil is compacted or graded and removed, thus reducing soil storage. Vegetation is cleared and replaced with house, lawns, and parking lots. Roads are paved and cover vast amounts of the original soil surface. In periods of low precipitation when water has time to drain, detention storage is still available providing that the water has some way of reaching the soil. If the water is guttered and piped to storm sewers or streams, then very little will reach the soil. Without trees or other deeply rooted plants to remove the soil water bound to soil particles, retention storage may remain almost full and not be available for storm storage. In a two-foot deep soil with very low ET due to lack of deep-rooted vegetation, retention storage may remain almost full. This would decrease available soil storage by 2-4 inches depending on the soil type and depth and presence of glacial till layer.

In summary, studies of forest hydrology give us an understanding of how alteration of the land affects the hydrologic cycle. Changes in urban areas are analogous to those due to harvest but are more severe and more long lasting. To minimize excess storm flow generation in streams, it is crucial to maximize natural areas, provide for infiltration opportunity, and minimize the generation of overland flow. Compared to other regions in the United States and the world, some Puget Sound streams still have some ecological functions intact. Now is the time to recognize that certain activities are impacting these streams and to limit the impacts. The longer we wait, the harder and the more expensive it will be to restore the streams, if it is possible at all.

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Technical Details

The above analysis was performed using the U.S. Environmental Protection Agency HSPF computer program, SeaTac Airport hourly precipitation data (October 1948 through September 1996), Puyallup daily pan evaporation data (same period of record), and U.S. Geological Survey regional HSPF parameter values for Puget Sound lowland watersheds in King and Snohomish counties.

The standard EIA values for rural residential (4%), suburban residential (26%), multi-family (48%), and commercial (86%) development were used. The impervious land use category is 100% EIA. Rural residential with forest assumes 5-acre residential lots with 2 acres of forest remaining on each lot. Rural residential with pasture assumes all of the forest has been replaced with pasture.

DOE pond sizing was computed using the SBUH procedure described in the DOE publication, Stormwater Management Manual for the Puget Sound Basin, Volume III - Runoff Control, February 1992.

HSPF flood frequency analysis was computed using Log Pearson Type III procedures described in the U.S. Water Resources Council publication, Guidelines for Determining Flood Flow Frequency, Bulletin #17B of the Hydrology Committee, revised September 1981.

Flow duration analysis was conducted using the HSPF utility DURANL and 420768 hours (48 years) of simulated flows from each of the nine land use categories.

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Everything else is our fault.

BEYOND INNOVATIVE DEVELOPMENT: SITE DESIGN TECHNIQUES TO MINIMIZE IMPACTS TO SALMON HABITAT

By: Tom Holz, Tom Liptan and Tom Schueler

Recent research indicates a strong link between total impervious area and the degradation of stream and wetland ecosystems, particularly salmon habitat (May et al, 1997). The research indicates that the degradation threshold is passed at about 5 to 10% watershed impervious area in Puget Sound lowland streams. Such a low impervious cover limit present a serious challenge to future watershed development, as nearly all traditional development designs (TDD) will exceed the 5 to 10% limit.

In this paper, we explore four questions. The first question is what kind of minimum watershed functions are needed to maintain on salmon habitat in the eco-region. Second, to what extent can "innovative" development designs (IDD) contribute to maintaining these functions? Innovative development designs refers to new site planning techniques that utilize open space subdivisions, narrower streets, greener and smaller parking lots, stream buffers, stormwater practices and other measures to reduce impervious cover and conserve natural areas. It is argued in this paper that IDD techniques alone, however, will be insufficient to maintain the minimum watershed functions to protect salmon habitat in most future growth areas.

The third question explores "Zero-Impact" Designs-- a series of techniques and practices that have not been widely applied in the Pacific Northwest, but may have potential to sharply reduce the "effective impervious area" of new watershed development beyond what can be achieved by IDD. Examples of ZID techniques include: eco-roofs, roof-gardens, rain-barrels, bioretention, alternative paving surfaces, soil amendments, bioretention, reforestation, filter strips and filter-swale systems. The fourth question asks whether improvements in the design of individual development sites can cumulatively meet minimum watershed functions, and explores what implications this may have for regional watershed management in the Pacific Northwest.

1. Watershed Performance Criteria To Protect Salmon Habitat:

Based on our current understanding of PSL streams, the following general watershed functions appear to be necessary to protect salmon from the effects of watershed development:

1. Preserve a minimum percentage of forest cover in the watershed to maintain some of the pre-development storage and evapotranspiration functions.

2. Preserve and manage a suitable riparian forest buffer zones along the stream network, and ensure that any buffer crossings will not create barriers to fish migration now or in the future.

3. Reduce the effective impervious area of the watershed to as near as zero as possible. This requires the design of a stormwater conveyance system that promotes sheetflow and storage, and discourages the collection and concentration of runoff.

Minimizing Effective Impervious Surface

Reduction of "effective" impervious surface to zero implies more evapotranspiration and infiltration of runoff. But the poor soils in the Puget Sound basin preclude infiltration from "traditional" development with its vast seas of impervious surfaces. If runoff is collected in any significant volume such as from a 60 foot wide road with curb and storm drains, it cannot be infiltrated and there is no place to route it except to surface water. Even a few gallons per minute of concentrated runoff cannot be infiltrated because the target zone for such infiltrate, the thin soils over the impervious till layer, do not have the capacity to store such quantities especially in the wet season.

To accomplish infiltration on poor soils, runoff cannot be collected. It must instead reach the water management "engine" of the forest within feet of where it falls as precipitation. To meet this constraint (and also to maintain sufficient forest cover to preserve predevelopment forest functions), development must take place, literally, between the trees. Examples of this kind of development (designed for totally different reasons) can be found in some older subdivisions in the Northwest. To accomplish this, impervious surface must be reduced to the maximum extent possible; impervious surface must be contained in discreet and unconnected blocks; AND discreet blocks of impervious surface must be buffered by forest. Simply put, we must build between the trees.

2. Innovative Development Design.

It is possible to develop land in a manner that sharply reduces the amount of impervious cover created and the amount of natural cover that is lost. It should be noted that most communities will need to substantively revise and reform their current subdivision and planning codes to allow developers to practice these innovative development techniques. In particular, communities need to feel that concerns about the marketability, liability, maintenance, public safety, parking and homeowner acceptance are fully satisfied before changing from the traditional development patterns. To help guide this process, a group known as the Site Planning RoundTable, representing over thirty national organizations that have a strong influence on how land development occurs, agreed to a set of 22 model land development principles that promote innovative development.

Residential Streets and Parking Lots (Habitat for Cars)

1. Design residential streets for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on traffic volume.
2. Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.
3. Wherever possible, residential street right-of-way widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains should be located within the pavement section of the right-of-way wherever feasible.
4. Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should be considered.
5. Where density, topography, soils, and slope permit, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.
6. The required parking ratio governing a particular land use or activity should be enforced as both a maximum and a minimum in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance taking into account local and national experience to see if lower ratios are warranted and feasible.
7. Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.
8. Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in the spillover parking areas where possible.
9. Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.
10. Wherever possible, provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

Lot Development (Habitat for People)

11. Advocate open space design development incorporating smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.
12. Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.
13. Promote more flexible design standards for residential subdivision sidewalks. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.
14. Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.
15. Clearly specify how community open space will be managed and designate a sustainable legal entity responsible for managing both natural and recreational open space.
16. Direct rooftop runoff to pervious areas such as yards, open channels, or vegetated areas and avoid routing rooftop runoff to the roadway and the stormwater conveyance system.

Conservation of Natural Areas (Habitat for Nature)

17. Create a variable width, naturally vegetated buffer system along all perennial streams that also encompasses critical environmental features such as the 100-year floodplain, steep slopes and freshwater wetlands.
18. The riparian stream buffer should be preserved or restored with native vegetation. The buffer system should be maintained through the plan review delineation, construction, and post-development stages.
19. Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access, and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.
20. Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas.
21. Incentives and flexibility in the form of density compensation, buffer averaging, property tax reduction, stormwater credits, and by-right open space development should be encouraged to promote conservation of stream buffers, forests, meadows, and other areas of environmental value. In addition, off-site mitigation consistent with locally adopted watershed plans should be encouraged.
22. New stormwater outfalls should not discharge unmanaged stormwater into jurisdictional wetlands, sole-source aquifers, or sensitive areas.

While implementation of the RoundTable principles is both economically and environmentally desirable, and a clear improvement over the traditional development designs, available evidence suggests that they still may not reduce stormwater enough to prevent degradation of salmon habitat. This is illustrated by two real case studies, where the innovative land development principles have been applied to "re-design" traditionally developed sites. A simple model was used to compute the reductions in stormwater flows, pollutant loads and construction costs. While the analysis indicates that the application of innovative development principles does result in impressive reductions in all three factors, the reductions are not sufficient to meet the watershed function criteria outlined earlier.

3. Zero-Impact Design.

The primary reason why innovative development designs cannot meet the watershed function criteria is that they still produce large impervious units, in the form of rooftops and roadways that concentrate stormwater flows well beyond the pre-development condition. To achieve a "truly" zero-impact design, it is therefore necessary to convert these large impervious units so that they effectively function as pervious ones. This challenging task requires a fundamentally different approach toward design, and might involve:

Eco-roofs to Reduce Runoff

An eco-roof is a term used in Portland to describe a green living roof of vegetation and soil. This type of roof is European in origin and is referred to in Europe as a "green roof or extensive roof garden." It is a light weight (5-25 psf) roof system consisting of a synthetic waterproof membrane, a drainage layer, a thin soil layer (2-4 inches), and is covered with specific plant species adapted to the extremes of a rooftop environment. The eco-roof is a very low maintenance, self-sustaining plant/soil community without need of irrigation, fertilizers, or pesticides. It is of relatively low cost, about 30% more than a conventional roof, but lasts about 50% longer. Based on a German survey 82 cities in Germany offer some form of financial assistance to building owners who retrofit their rooftops with eco-roofs.

Eco-Roof Application

The eco-roof is mainly intended for its environmental functions and can be applied to retrofit existing buildings and for new construction. If we assume that one third of the impervious surfaces of an urban landscape are rooftops, then a significant opportunity exists for the eco-roof application. For example, the estimated total area of rooftops in Portland is 20 square miles, and at full build-out the rooftops will be about 24 square miles. Total area of the City of Portland is 145 square miles, with the estimated total impervious surfaces projected to 45% at build-out. Considering also that nearly all of these roofs will have to be replaced within the next 30 years, every building owner will be faced with a major capital expense.

Eco-roof Benefits

Are eco-roofs "truly" a zero expense technique? Probably not, but when compared to conventional roofs an eco-roof offers far more environmental and potential economic benefits. These benefits are multi-dimensional. Table A provides a comparison of eco-roofs to conventional roof systems to help provide a better context upon which to judge the characteristics of each. Most of the information has been obtained from sources listed below the table. Some information (indicated with *) is based on BES initial studies and speculation.

TABLE A – COMPARISON OF ECO-ROOFS AND CONVENTIONAL ROOFS

SUBJECT	ECO-ROOF	CONVENTIONAL ROOF
Stormwater:		
Retention:	15-35% wet season	0%
*peak flow:	Mitigates average wet season intensities	0% mitigation
	Attenuates 100% of warm season high intensities	0% attentuation
*temperature	0-35% hot runoff warm season	90-100% hot runoff warm season
	Reduces thermal increase in runoff	Causes thermal increase in runoff
Quality	Retains atmospheric deposition and retards roof degradation; potential for nutrient discharges	Allows atmospheric deposition to runoff and doesn't protect roof materials from degradation
Air quality:	Filters air, stores carbon and releases oxygen	None
Energy:	Approaches predevelopment air/surface energy relationship, allows almost year round evapotransporation of about 60% annual precipitation	Major impervious surface contributor to ozone problem, no transporation, evaporation at about % annual precipitation
***Greenspace:**	Can replace 100% of greenspace lost to building footprint (although greenspace is not of same quality)	None
Habitat:	Provides habitat and for some insects and birds	None
***Livability:**	Buffers noise, eliminates glare, alternative aesthetic	Conventional non-aesthetic
Cost & Life:	About 30% more expensive for construction including retrofits, life span 36 years about 50% longer than conventional roof	Approximately $2-$10 per square foot for new construction and $4 - $15 per square foot for retrofits, average life span 24 years
Maintenance:	After plants are established, once a year to assure drains are not clogged	Once a year to assure drains are not clogged

Sources: Sarnifil Co. Sarnevert Division, Switzerland; Soprema, Inc. Ohio, USA: North American Wetland Systems/Re-natur Minnesota, USA; Garland Co. Ohio, USA; Schoop Co. Switzerland; Grodania Co. Denmark; Bernd W. Drupka (Consultant) Germany; Rasen Co. Germany; Silke Schilling (consultant) Germany;

*City of Portland, Bureau of Environmental Services estimation

Road Runoff Management

Traditional roads and streets provide 12 feet of paving per lane for a pair of vehicle tires that are about 7 inches wide each. The wider pavement strips allow vehicles to travel faster. In quiet neighborhoods, the accommodation of high speed travel is a convenience once provided we often do our utmost to retake through speed bumps and traffic calming devices.

In neighborhoods are the best opportunities for pavement reduction. Streets can be made one way and all but the most minimal driving strips are needed to safely carry the very low volumes of traffic. This road section shows a one-lane street (with parking) where impervious surface has been reduced to 11% of the right of way. The portions of the cross section shown as vegetated are proposed to be paved with lattice blocks which will handle parked cars and carry the occasional "slip" from the driving strips. The road ballast provides storage for 4 to 6 inches of precipitation allowing slow migration of trapped precipitation to the adjacent forest. This road section would produce little or no overland flow runoff.

Higher speed arterials provide a greater challenge for impervious surface reduction but the same principles apply: actual impervious surface reduced to a small fraction of the right-of-way and a forest canopy covering as much of the driving lanes as possible. Ironically for higher speed roads, right-of-ways may have to be wider (goes against the goal for more dense development) to allow adequate buffer of forest necessary for acceptance of the extra runoff generated by the road.

Runoff Reduction Means Native Vegetation in Landscaping

Evapotranspiration from forest is about 50% of annual precipitation. From lawns it is less than half that. Furthermore such artificial landscapes require massive amounts of chemicals to resist nature's intent. If too much of a watershed is converted to lawns and forest buffers around such landscaping are insufficient to absorb the additional runoff, stream discharge increases and water quality decreases until fish habitat is no longer viable.

4. Site Design and Watershed Function:

Can improvements in the design of individual development sites cumulatively meet minimum watershed functions in most watersheds? The answer is probably no, unless they are performed in the context of an overall watershed plan that includes sub-watershed-based zoning, protection of sensitive areas, buffers, erosion and sediment control, stormwater management, non-stormwater discharges and watershed outreach programs. At a regional level, it may well be necessary to direct new growth into subwatersheds that are already well developed, and to manage these more urban systems in different ways.

LEGAL AND INSTITUTIONAL CHANGES TO ALLOW LOW IMPACT DEVELOPMENT

By: Allen Miller
(Presented at the conference by Thomas Bjorgen)

I. Right now the regulatory duties are spread among at least three levels of government and then among many different agencies and groups within those three levels. This framework creates many unrelated sets of regulations without a central governing agent. An example of what that framework looks like is:

Federal & State

- U.S. Army Corps of Engineers (Section 404 & Section 10 permit)
- Aquatic Use Authorization (Aquatic Lease)
- Coastal Zone Management Certification
- State Environmental Policy Act (RCW 43.21C & 197-11 WAC)
- Hydraulic Project Approval
- Aquaculture Permit
- Growth Management Act (also at local government level)
- Department of Fish & Wildlife
- Department of Natural Resources

Local Government

- Shoreline Management Act Permit (Shoreline Permit)
- Local Planning Ordinances
    -12 counties
    -34 cities

Other

- Tribal Planning
    -8 tribal reservations

II. Washington State's Future Will be Determined by One of Two Different Paths.

A. House Bill 2496

This bill follows Oregon's plan for preservation of salmon. It lays a foundation which, if approved, would allow the state to implement its own plan without the federal government's interference. It would be less drastic than the alternative.

Washington Department of Natural Resources House Bill 2496 passed 1998 session illuminates the Oregon effort to avoid the ESA listing salmon as an endangered species. It is a plan to avoid federal intervention which could be devastating to the economic growth in the Puget Sound area. (Not only to fishermen, but on the whole economic well being of this area.)

(I believe an analogy to state controlled changes would be the Growth Management Act which requires adoption of regulations to protect critical areas (including wetlands). Although the GMA may cause a substantial amount of paperwork and prevent some construction or changes on certain properties, it is nothing in comparison to the changes the Puget Sound would be subject to from the ESA. The main advantage is that the state is able to apply its own balance test.)

THE MAJOR THREAT TO FISH & WILDLIFE IN PUGET SOUND IS URBANIZATION:

-Conversion of land to commercial or residential uses
-Problems associates with development
-Dredging or filling of important habitat
-Disruptions of hydrological systems
-Increased erosion along the shoreline
-Degradation from urban contaminants

THE EFFECTS OF URBANIZATION ON THE ENVIRONMENT ARE:

-buildings (even single houses or "rest area" facilities)
(which displace or corrupt the natural habitats of animals)
-introduction of new plants to the area (which may stifle
natural plant systems or cause disruption in the form
of erosion, loss of food for animals, increased insects)
-increased use of land by people
    -recreational use (hiking, fishing, hunting, bikes, horses, creation of trails, . . .)
-increased use of nearby roads and highways
    -the need for more roads or larger roads, pollution from automobiles, littering, noise . . .)
-increased use of waterways, including more docks and water-housing (which cause pollution, noise, interference in the species life cycles)

EXAMPLES OF CHANGES WASHINGTON STATE COULD MAKE OR CHANGES WHICH THEY HAVE MADE WHICH MAY PRECLUDE AN ESA INTERVENTION

1) National Marine Fisheries Service (NMFS) has proposed designating marine near shore habitat in Puget Sound as a critical habitat for chinook.

The definition of "near shore habitats" is found on page 2 of the Puget Sound Near Shore Habitat Regulatory Perspective: A Review of Issue and Obstacles. That report focuses on land 200 ft landward of the ordinary high-water line to the shallow subtidal zone. (This land falls w/i the jurisdiction of the state's Shoreline Management Act (SMA) that significantly affect near shore habitats.)

2) Changes recently made to other national parks could be enacted in Washington state parks, i.e., the Grand Canyon and Yellowstone Park. Changes have included higher entrance fees, limits to number of visitors, reduction or elimination of automobiles and vehicles, reduction or elimination of pack animals allowed, reduction of the length of visits, reduction in park hours and days open, ...

Washington State parks have already increased fees. Other regulations we have seen recently, include the reservation system (which limits the number of visitors), gates at the entrance of these parks which can limit vehicle access during seasons where automobile travel would damage the habitat and shortening of hours and seasons. There are also limits on the number of fishing tournaments allowed on state lakes.

3) Increase in fees for hunting and fishing licenses, as well as lotteried hunting and fishing permits for threatened species. The seasons could also be shortened.

4) A longer waiting period and increase in fees for building permits.

5) More complete applications and environmental impact statements required for all building permits.

6) RCW 43.21C.110 (Content of State Environmental Policy Act rules), states that elements of the environment both "natural" and the "built" may be regulated. In other words, the statute gives authority to regulate on both "natural" environments and "built" environments.

B. Endangered Species Acts (ESA)

Enactment of the ESA would place control of the preservation of salmon in the hands of the federal government. Implementation of ESA could mean major economic changes throughout our state. The ESA makes it illegal to "take" any fish or wildlife species listed as endangered. "Take" includes "harm". And harm means "any act which actually kills or injures wildlife, including significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding or sheltering."

The current laws regulating any of the above activities may be in jeopardy if ESA is enacted for salmon preservation. Enactment of the ESA would force our state legislature to change laws which may effect our state's future economic growth and private property rights.

Depending upon the current level of damages occurring, the changes necessary may be rather drastic compared to our current regulations. These changes might also affect grandfather clauses and exception policies (perhaps totally eliminating them).

(An example of what would happen if ESA gets involved is the "spotted owl" or those "tiny fish" things that stopped some dams...)

The effects may be drastically felt on every person living in the state, including: fishermen (recreational and professional), contractors, recreational users, loggers, rafters, homeowners, marinas, tourists, agricultural farmers (maybe even as far away as eastern WA, ID or OR), ferry travelers, boaters, Native Americans, consumers of electricity (wherever Bonneville power is sold)... There will be virtually no one in this area left untouched.

Specifically, laws would need to be changed whenever any of these activities (and perhaps a much longer list) had an adverse affect on the species named by ESA:

-construction
-commercial use
-recreational use
-pollution control (of all kinds-including noise)
-Native American treaties
-treaties and agreements with Canada
-enforcement and penalties for violations

State fishing & hunting regulations would need to be modified to change the "takings" allowed or restricted as the case may be. Other changes may mean the reduction of hunting or fishing seasons, not only to reduce the number of takings, but also to limit the number of people and the length of time those people are in that "near habitat."

Just to name a few specific types of city-county laws that would need to be amended:

-Thurston Cnty section 17.09.08- et all . . .
    Expansion of the use of "environmental checklist"

-Thurston Cnty section 17.15 . . .
  - Changes in Review Standards
  - Changes in buffer zones, exceptions, allowable uses...
  - Special management areas
  - Rating systems

-City ordinances
  - sections 14.04 (Environmental Policy)
  - sections 16.04 (Building Codes)
  - sections 17.16 (Preliminary Plat)
  - sections 18.60 (Uniform Development Code

COULD THE ESA IMPACT DEVELOPMENT REGULATIONS?

1. ESA is intended to protect endangered species from "harm".

2. Fish need buffers and a reasonable range of flow from base to maximum flood.

3. Drainage standards in recent years were intended to protect habitat (ie, "harm").

4. Critical areas ordinances provide steam buffers which might protect endangered species from "harm".

5. Neither CAO's or drainage standards are adequate.

6. Drainage standards based on a false model.

7. What does recent literature say about development and salmon habitat?

8. How much buffer is adequate?

9. "Ideal" development; no impact on habitat.
   - no sale of lots (developer responsible for system protection, buffers, etc).
   - no clearing before development
   - no stream crossings (less than l per kilometer)
   - 100 to 300 foot buffers on streams including the smallest of tribs).
   - no drainage system
   - no direct discharges to streams
   - minimum impervious surface
   - lots of infiltration aids
   - vegetated roof tops
   - higher tolerance to ponding

10. What does minimum impervious surface mean?
    - most pavement is for cars
    - narrower roads
    - one way roads
    - replace most pavement with lattice block
    - roads and homes place among the trees
    - smaller building footprints (up - not out)

- parking under buildings
- shared driveways
- lattice block drives, garage aprons,
- porous pavement sidewalks; tennis courts; etc.
- decks instead of concrete patios

11. Laws to be Amended
    - No NPDES permits for non-complying development
    - State Technical Manual (zero discharge; no treatment if immediately infiltrated)
    - Forest Practices Act (logging & conversion disallowed)
    - Hydraulic Project Approvals (none granted for new outfalls)
    - Local Drainage Ordinances
    - Critical Areas Ordinances
    - Zoning ordinances
    - Road standards
    - Building codes
    - Fire codes

12. Difficult laws to work around
    - ADA

13. Difficult Issues
    - Taking (of buffers; timber)
    - Bonding for the protection of infiltration
    - Homeowners Association enforcement of building standards, encroachment on buffers, tree/vegetation cutting, architectural standards.
    - Existing small lots on stream or fist order tribs which are rendered unbuildable by buffers.

POSSIBLE SOLUTION FOR UNITED COMMUNITY EFFORT TO PRESERVE SALMON & THEIR HABITAT

A possible solution to this problem of "too many different regulations" would be to place total control of all regulatory duties within an ad hoc, or permanent if necessary, committee made up from members of each of the different agencies and groups currently in charge of regulating. That new committee would then oversee the consolidation of regulations into one workable plan for the future of Puget Sound.

Possibly including representatives from:

NEPA, SEPA, ESA
National Park Services
Forest Service
Bureau of Land Management
Other states with geographic relations or similar problems

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