ACTIONS for WATERSHED HEALTH

2005 Portland Watershed Management Plan

SUMMARY of the Framework for Integrated Management of Watershed Health

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ENVIRONMENTAL SERVICES
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working for clean rivers

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CHAPTER 1

Introduction

In the Pacific Northwest, rivers and the lands they drain are a living link with the region's history and heritage. They have supported human life for millennia, powered modern economic growth and development and nurtured species such as salmon and Douglas fir that have become icons of our unique region, people and lifestyle. In Portland, Oregon, it is the Willamette River, its tributaries and their watersheds that, economically and culturally, have defined the city for decades and continue to do so today.

However, during the last 150 years human activity in Portland has taken its toll on the area's rivers and watersheds. Local landscapes have been transformed, natural processes have been disrupted and habitats have become fragmented. Water quality in the area's rivers and streams has deteriorated, and populations of some native species have declined or disappeared. As a consequence, the City of Portland is subject to the requirements of a host of state and federal environmental laws and faces decisions about how to manage its rivers and watersheds into the future.

> **What is a watershed?**
>
> A watershed is a geographic area that includes a river or stream, its tributaries and the lands they drain.

Clearly, in an urban area it is not possible to re-create historical, presettlement conditions. Yet Portland's citizens and City Council repeatedly have stated that they want local rivers, streams and watersheds to be clean and healthy—as a way to protect human health, enhance community livability, invigorate the economy and support the area's native species and biological communities. Maintaining healthy watersheds also is a way of preserving for future generations the natural legacy on which our community was built, and that in some sense still defines who we are.

To advance these interests, the City of Portland has developed the *Framework for Integrated Management of Watershed Health*, which establishes urban watershed health goals and offers a process the City can follow to achieve them.

What Is the *Framework*?

The *Framework for Integrated Management of Watershed Health* describes how the City of Portland plans to go about achieving and maintaining healthy conditions and ecological functions in its urban waterways—specifically the lower Willamette River, the Columbia Slough, Johnson Creek, Fanno Creek, Tryon Creek, and Balch Creek and other tributaries—and their watersheds. The process is intended to do the following:

- Generate a base of scientific information about Portland's watersheds that can inform all City government decisions that affect watershed health.
- Integrate the City of Portland's responses to the federal Endangered Species Act, Clean Water Act, Safe Drinking Water Act and Portland Harbor Superfund listing across City bureaus and programs, to save money and increase effectiveness.

- Guide development and implementation of watershed management plans that will establish goals, objectives and benchmarks for each urban watershed and specify actions to improve watershed health.
- Guide City activities that do not focus on the environment but can affect it, to ensure that the activities foster healthier watersheds.

In essence, the *Framework* describes how the City will get from broad watershed health goals to on-the-ground actions that improve watershed health. Success will come in part by focusing on the root causes of environmental problems, instead of their symptoms (that is, fixing problems instead of merely managing them), and by designing urban activities so that they enhance rather than degrade watershed conditions.

Instead of being a onetime undertaking, the process presented in the *Framework* is iterative and ongoing. The City will use it to manage the area's watersheds into the future.

The *Framework* is the first step in this larger undertaking. It is the technical foundation the City will rely on when dealing with the aquatic, streamside and upland components of the ecosystem that are essential to healthy watersheds.

Why Develop the *Framework*?

Several factors spurred development of the *Framework* and the watershed management process it presents, including citizen recognition of the value of healthy watersheds in improving community vitality and livability and City government's belief that thriving natural systems provide a stronger economic base than degraded systems. This belief is expressed in part through the City of Portland's River Renaissance vision, which was endorsed by the City Council in March 2001. The vision involves a communitywide effort to revitalize the Willamette River and its tributaries so that they play an integral role in the natural, economic, urban and recreational life of the city. Ensuring a clean and healthy river for fish, wildlife and people is one part of the River Renaissance vision.

The *Framework* was also developed to help address federal regulatory requirements and City Council resolutions related to them. Specifically, steelhead trout and Chinook salmon that use Portland's waterways were listed under the Endangered Species Act (ESA) in 1998 and 1999. In response, the City Council adopted a resolution stating that the City will assist with the recovery of listed species. A second resolution endorsed the development of a comprehensive framework to guide the City's response to the ESA, the Clean Water Act (CWA), the Safe Drinking Water Act, Superfund and other laws, and City objectives. Lastly, in 2000 the Portland Harbor was added to the National Priorities List (NPL), making it a Superfund site under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); a third City Council resolution expressed the City's interest in playing a leadership role in determining cleanup and restoration strategies for the harbor. The City must take certain actions to respond to these recent listings and comply with other federal laws related to watershed health, just as for years the City has had obligations under the CWA because Portland's combined sewer overflows and other discharges have affected water quality in local waterways.

At the regional level, the City must comply with Titles 3 and 13 of Metro's *Urban Growth Functional Management Plan*, which implement statewide land use goals related to the impact of development on streams, rivers, wetlands, floodplains and other natural resource areas.

The City also is coordinating and sharing insights with other entities involved in planning to restore fish and wildlife and improve water quality and watershed conditions throughout the Northwest. The *Framework* assists the City in both of these efforts.

A Definition of Healthy Urban Watersheds

Portland's citizens and government have said that they want healthy watersheds, but actually defining a healthy watershed can be complicated, particularly in an urban area. Does it mean meeting state and federal environmental requirements? Having rivers in which people can fish and swim? Fully restoring populations of native species? The Willamette River and Balch Creek watersheds differ greatly—is what's healthy for one healthy for the other? Is it even realistic to try to restore watershed health in an urban area?

The City of Portland believes achieving healthier watersheds is possible in urban areas, but—because each watershed is unique—what that looks like will differ from one watershed to the next. In general, though, the *Framework* defines a healthy urban watershed as follows:

> *A healthy urban watershed has hydrologic, habitat and water quality conditions suitable to protect human health, maintain viable ecological functions and processes, and support self-sustaining populations of native fish and wildlife species whose natural ranges include the Portland area.*

This definition is in keeping with the *Framework*'s multi-pronged vision of the future of Portland's watersheds:

> *Portland's urban form supports both a thriving economy and natural processes that maintain healthy ecosystems. Portland protects and restores properly functioning conditions throughout its watersheds to provide clean water and support abundant, self-sustaining populations of native fish and wildlife. These efforts enhance the livability and vitality of Portland for its citizens and help meet the City's obligations under the Clean Water Act, the Endangered Species Act, Superfund, the Safe Drinking Water Act and other laws.*

Goals for Watershed Health

The level of watershed health that is possible to attain varies from one watershed to the next, so the *Framework* approach involves setting unique objectives for each watershed. However, all of the objectives will support four main goals the City has for watershed health:

- **Hydrology:** Move toward normative[1] flow conditions to protect and improve watershed and stream health, channel functions, and public health and safety.
- **Physical Habitat:** Protect, enhance and restore aquatic and terrestrial habitat conditions to support key ecological functions and improved productivity, diversity, capacity and distribution of native fish and wildlife populations and biological communities.

[1] A normative flow has the magnitude, frequency, duration and timing essential to support salmonids and other native species and resources.

- **Water Quality:** Protect and improve surface water and groundwater quality to protect public health and support native fish and wildlife populations and biological communities.
- **Biological Communities:** Protect, enhance, manage and restore native aquatic and terrestrial species and biological communities to improve and maintain biodiversity in Portland's watersheds.

If watershed conditions support a thriving salmon population, the watershed is almost certainly healthy and functioning properly.

The *Framework* focuses on the health of the aquatic components of the ecosystem, in particular the health of salmonids (salmon and trout) and their habitats, because salmonids are good measures of the health of most key watershed processes—especially hydrology, water quality and river and streamside habitats. If salmon populations are healthy, it can generally be assumed that watershed conditions are healthy; in that sense, salmon are akin to canaries in coal mines. However, the needs of terrestrial wildlife species and their habitats must also be addressed if healthy watershed conditions are to be achieved. For this reason, many of the scientific principles the *Framework* is based on apply to terrestrial species as well as aquatic species.

What Is the Watershed Management Process?

The *Framework* presents a watershed management process that can be used to address multiple watershed-related goals simultaneously, whether those goals are to assist in salmonid recovery, protect key plant communities or wildlife habitats, achieve the River Renaissance vision or comply with the Clean Water Act. Simply put, the watershed management process recognizes relevant scientific principles and applies them to the following:

- Describing watershed conditions
- Diagnosing watershed problems and understanding properly functioning watershed areas
- Identifying, prioritizing, selecting and implementing actions that will solve watershed problems and maintain properly functioning areas, while taking into consideration various economic and social factors
- Monitoring results over time to refine techniques and measure progress in meeting goals

What is adaptive management?

Adaptive management is a way of systematically improving restoration activities by learning from experience and new information. It requires frequent monitoring and fine-tuning of restoration strategies.

Iterative and ongoing, the process uses adaptive management to adjust watershed activities over time. Eventually, applying the watershed management process will protect or reestablish key ecological functions affected by urban growth and development. At the same time the process will help the City of Portland achieve its own watershed-related goals and comply with state and federal laws.

The watershed management process will guide development of watershed management plans for each urban watershed. These plans will identify goals, objectives, targets and benchmarks for the watersheds and specify actions to improve watershed health.

A Unique Approach

The City already has taken many actions to improve watershed health, but the *Framework*'s approach differs from past approaches in several ways:

- It is scientifically based.
- It uses clear, measurable goals, objectives and benchmarks.
- It involves monitoring progress toward the goals, and refining actions and analytical tools when necessary.
- It is designed to improve overall watershed health, not just meet individual regulatory requirements.
- It strives to *solve* environmental problems and avoid planting the seeds of new ones.
- It integrates the efforts of multiple City bureaus and programs and stresses the importance of partnering with other jurisdictions and stakeholders in the region.

Integration is an important aspect of the *Framework* approach. Different City bureaus and programs will be coordinating work plans and timelines. They will draw on the same data and use commonly agreed-upon methods when taking actions to improve watershed health. They will all be working from the same watershed management plans, which set forth the goals, objectives, benchmarks and approved actions for each watershed. The result will be bureau activities that complement one another; increased consistency, efficiency and effectiveness; and the ability to measure overall progress in achieving the City's watershed goals.

The *Framework* process provides a lens through which all City activities can be viewed, so that their positive and negative impacts on watershed health can be understood.

Additionally, the *Framework* process will provide guidance to all City programs that affect watershed health. This will ensure that transportation, capital improvement, urban renewal, land use and other activities (including new projects) are compatible with watershed health goals.

Portland Within the Region: What We Do Matters

Portland's watershed management activities will be taking place at the local level but within the context of a larger, interconnected ecosystem that extends through much of the Pacific Northwest. For example, every salmonid migrating to and from every tributary of the Willamette River (and many Columbia River tributaries) must pass through Portland. And as water moves from upper river reaches toward the Columbia, the cumulative effects of land uses, agriculture, hydropower and flood control throughout the region are manifested in Portland. This ecological link means that the conditions in Portland's watersheds affect—and are affected by—watershed health in communities throughout the region.

Given this regional context, the City of Portland is active in many local, state and regional efforts aimed at improving conditions of fish and wildlife and their habitats in the Willamette and Columbia River watersheds. By participating in these efforts, Portland hopes to both improve the conditions of its watersheds and do its part to contribute to regionwide improvements in watershed health.

CHAPTER 2

Scientific Foundation

The City of Portland is basing its watershed management process on ecological principles that are supported by scientific research. The principles fall into three main categories:

- Primary ecological principles
- Principles of river, wetland and upland ecology
- Principles of salmonid ecology

To achieve healthy watersheds, both aquatic and terrestrial components will need to be addressed.

These ecological principles serve as the foundation for restoration guidelines that will guide the City of Portland's watershed improvement efforts. The principles and guidelines are summarized below and described in detail in the *Framework for Integrated Management of Watershed Health,* which includes extensive scientific citations.

Primary Ecological Principles

1. Ecosystems are dynamic, resilient and develop over time.
2. Ecological systems operate on various spatial and time scales that can be viewed hierarchically.
3. Habitats develop and are maintained by processes related to biotic and abiotic components of the ecosystem.
4. The abundance, productivity and diversity of organisms are integrally linked to the characteristics of their ecosystems.
5. Species play key roles in developing and maintaining ecological conditions.
6. Ecosystem function, habitat structure and biological performance are affected by human actions.
7. Biological diversity allows ecosystems to accommodate environmental variation.

Change Is Constant. The seven primary ecological principles describe the function and dynamics of ecosystems, and how species respond to and interact with them. A key concept in these principles is that ecosystems change over time. Ecosystems are disturbed by fires and floods, logging and commercial development. Being resilient, ecosystems can absorb a certain amount of disturbance and still maintain their original character. But beyond a certain point, natural or human-caused disturbances can shift an ecosystem into a new and possibly less desirable configuration—one that favors different species and ecological interactions. It is this type of change that can open the door for nonnative species that can compete with juvenile salmonids and native wildlife. Often, ecosystems in urban areas are particularly vulnerable because their resilience has been reduced by near-constant human disturbances.

One source of change within ecosystems is seasonal, annual and multi-year variation: rivers flood, fish populations rise and fall and forest fires break out. These natural variations spur the development of a diversity of habitats whose presence, in turn, helps keep ecosystems healthy and functioning. Although seasonal and annual variation can be anticipated, no two years, seasons, decades or even centuries are the same, so conditions vary greatly over time.

What is an ecosystem?

An ecosystem is a complex community of species, habitats and environmental conditions that functions as an integrated system.

Unfortunately, the same natural variation that fosters diverse habitats can be an obstacle to humans, who prefer predictable, controllable natural processes for the sake of public safety and economic stability. Fish hatcheries, dams and fire suppression measures represent human attempts to stabilize the environment and make yields of fish, irrigation water and timber even and reliable. This is probably an unrealistic goal because it runs counter to the fundamental nature of ecological systems to be constantly changing.

Looking at Multiple Scales. Ecosystems exist on a variety of scales, from regional (the Pacific Northwest) to local (Johnson Creek) or even smaller (a particular stretch of Johnson Creek). In trying to restore watershed health, management decisions must consider ecological "problems" from multiple scales: What processes occur at the regional level? Watershed level? Site level? Understanding a problem from various scales clarifies which information and actions are needed to solve the problem, how long a solution might take and what other jurisdictions or resource management agencies might need to be involved. This points to the need for regionwide coordination on issues of watershed health and raises the question of what role Portland can realistically and effectively play in the context of regional watersheds.

The Origins of Habitats. Habitats exist in specific localities, but they are created by processes that operate far beyond a specific location. For example, land uses throughout a watershed can affect the temperature and turbidity of its water and how much gravel is in the riverbed. When restoring habitat, it is important to identify the processes that form that habitat. Looking at geology, soils, hydrology, vegetation, topography and land uses at the watershed, basin and even regional levels is the correct place to start.

What are habitats?

Habitats are the resources and conditions present in an area that allow a species or group of species to exist and thrive.

River flow is one of the biggest shapers of aquatic habitat. In large rivers flow is often affected by dams, and in smaller rivers it is affected by impervious surfaces. To restore certain habitats it may be necessary to allow more natural flow variations, such as some controlled flooding that can reconnect floodplain areas.

Ecological Functions. Species and their environments are linked, having evolved together over time. Just as the ecological conditions in a given habitat allow certain species to thrive, so do individual species contribute to the healthy functioning of the ecosystem, creating a type of feedback loop. In a sense, each species has several ecological jobs to do, be it cycling energy and nutrients, structuring habitat or controlling the population of other species. Returning salmon, for example, transport ocean nutrients to headwater areas. Beavers create ponds. Bats help keep mosquitoes in check. If a species disappears from the ecosystem, that species' contribution to the healthy functioning of the ecosystem is lost and the ecosystem's ability to function properly is diminished. If a species is insulated from the ecosystem (such as through dam bypass systems and salmon barging), key ecological interactions are altered and the feedback loop is broken.

Humans are species, too. We play an integral role in the ecosystem and can choose to manage our activities so that they make the ecosystem more—or less—compatible with the needs of other species. For example, we may be able to reconnect the feedback loop by providing a limited piece of what the ecosystem is missing, such as by distributing the carcasses of hatchery salmon in streams to replace nutrients that wild salmon used to provide when they spawned and died in local streams. In many cases we need to learn more about the habitats and processes that fish and wildlife species need, and the ecological functions they provide.

Humans are species, too, and play an integral role in ecosystems.

Biological Diversity. Ecosystems are resilient when they are biologically diverse. As ecosystems change through time, biological diversity permits individual species to wax and wane while allowing the overall biological community to thrive. While a particular individual or population within a species might not survive natural or human-caused changes in the environment, other individuals or populations might—usually because they have a somewhat different set of genes and thus slightly different biological characteristics that make those individuals or populations better suited to the new circumstances. Because change cannot be predicted, neither can the specific future ecological circumstances in which species will need to survive—or the particular genes and biological characteristics that will give a species an edge. Thus, simplifying an ecosystem by reducing the variety of its species or habitats can undermine the long-term functioning of that ecosystem.

Principles of River, Wetland and Upland Ecology

1. Rivers are not separate from the wetland and upland areas they drain.
2. Watersheds are defined by and operate across the spatial and temporal dimensions of riverine, wetland and upland ecosystems.
3. Hydrologic modification (outside of normative flow regimes) and changes in upland land use can reduce habitat diversity, decrease native biodiversity, increase nonnative species and exacerbate water pollution, landslides and flooding.

The Scope of Watersheds. Rivers, wetlands and upland areas are connected, in part through water. Although a river itself exists only between two banks, its flowing waters inextricably link the other elements of the watershed: the upstream lands that it drains, the shallow aquifers that it recharges with water, the wetlands and floodplain areas that it periodically inundates. These elements reflect three of the four important dimensions of watersheds:

Water in a stream reflects the surfaces over and through which it flows before reaching the stream.

- **Longitudinal dimension:** the upstream-downstream connection of rivers and habitats, from steep, forested headwater areas to estuaries. This dimension comes into play, for example, when polluted stormwater is transported miles downstream.
- **Vertical dimension:** the connections linking groundwater, aquifers, rivers, vegetation and the atmosphere. River water seeps through the riverbed, saturating underlying soils and recharging shallow aquifers. Groundwater recharges the river. Trees take up groundwater through their roots and respire through stomata in their leaves.
- **Lateral dimension:** the connection of the river with adjacent lands (the floodplain) through flooding and the dispersal of species across the landscape. Periodic floods change surrounding habitats and deposit nutrients throughout the floodplain, creating areas of high biodiversity and ecological production that are hydrologically linked to the river at certain times of year. Plants and animals spread from one patch of habitat to another.

When ecological connections between habitats are severed, such as when humans attempt to control flooding, biodiversity is reduced.

The fourth dimension is time, as ecological conditions (temperature, river level, mix of vegetation, etc.) vary through the day, season, year and century. To understand watersheds scientifically, one must look at all four dimensions and the connections they create among habitats.

Effects of Hydrologic Modification. Humans have significantly modified both the hydrology of rivers and the ecological connections that rivers create. Dams have altered natural flood patterns, water temperatures, the degree of variation in daily water flow, and the amount and type of material (sediment, gravel, woody debris and nutrients) that river waters transport downstream and across floodplains.

What is hydrology?

Hydrology is the science that deals with the properties, distribution and circulation of water, both on and below the earth's surface.

In urban areas, filling, paving, piping, draining and development have reduced the amount of actual, physical habitat both in streams and on land. Much of that habitat has been replaced by impervious surfaces whose presence increases stormwater runoff and decreases groundwater recharge. Increased stormwater flows alter the stream hydrology, changing the river's speed, width, depth and connection to floodplains.

The combined effects of hydrologic modifications can be profound:

- Simplified structure of the river channel
- Increased erosion
- Compromised connections among habitats
- Substantial reductions in habitat diversity
- Increased water pollution
- Decreased native biodiversity
- Proliferation of nonnative species

Native species are consistently less abundant in river reaches where flows have been extensively modified than they are in unmodified reaches.

When a previously complex ecosystem, where native species thrived in a diverse network of habitats, is simplified both structurally and ecologically, it becomes less productive over time.

When Upland Land Uses Change. Every species needs habitat. In upland areas, though, terrestrial species often have been caught short. As land uses change and natural habitats are disturbed, invasive species such as English ivy and Himalayan blackberry easily find a foothold and the ecosystem can start shifting away from configurations that support native species. Also, when roads and buildings replace the forests, shrubland and grasses that native plants and animals depend on, there is simply less habitat available.

> **What are uplands?**
>
> Uplands are non-aquatic, non-streamside areas such as hillsides and meadows. Generally, they are uphill of rivers, streams, and wetlands.

Too often, the habitat that does remain exists in individual blocks or patches that isolate plant and animal populations. Species that normally use migratory corridors may not be able to do so. Less mobile species have difficulty dispersing and establishing new populations. As larger habitats are broken up into smaller patches, ecological processes are disrupted and, consequently, biodiversity is reduced. This happens partly because in small patches there is less of the “interior” habitat that many native species are adapted to and more “edge” habitat, which gives edge-adapted predators more access to interior species. Land uses affect the size, type, distribution and connectivity of upland habitat patches; these factors in turn help determine the viability and diversity of native plant and animal species.

Principles of Salmonid Ecology

1. Life history diversity, genetic diversity and metapopulation organization are ways salmonids adapt to their complex and connected habitats and are the basis of salmonid productivity and salmonids’ ability to cope with environmental variation.
2. Sustained salmonid productivity requires a network of complex, diverse and interconnected habitats that are created, altered and maintained by natural physical processes in freshwater, estuarine and ocean environments.
3. Restoration of salmonids must address the entire natural and human ecosystem, encompassing the continuum of freshwater, estuarine and ocean habitats where salmonids complete their life histories.

Chains of Habitats. Salmon are migratory species. To complete their life cycle, salmon use a chain of interconnected habitats that stretches hundreds of miles, from high mountain streams to estuaries to the ocean—a type of ecological highway. But just as there are genetic variations from one individual to the next, in any species, so too are there variations in (1) the geographical strings of habitat that different salmon populations need, (2) the times of year at which populations need those habitats, and (3) corresponding behavioral characteristics, such as the timing of migration or preferences in spawning habitats. For example, one returning salmon population might travel from the ocean to the Clackamas

River in the spring and then wait until fall to ascend a small tributary and spawn. Another population might migrate directly to the Clackamas in the fall for spawning. In following its own route and timing for migration, each population expresses its own life history. This variation from one population to the next is called life history diversity.

The Value of Life History Diversity. As with biodiversity, having a diversity of life histories within a species enhances that species' overall survival. The more life histories there are, the more likely it is that the biological characteristics, behavior and string of needed habitats of some of those populations will be well-suited to actual conditions. Originally, the life history diversity of salmon in the Willamette River ecosystem was substantial, owing to the system's varied topography, large number of tributaries, highly variable flow regime and oceanic circulation patterns. But numerous factors—human-caused hydrologic modifications among them—have significantly reduced the diversity of habitats and the corresponding salmon life histories.

Dependence on Habitat. It follows that, to maintain salmon populations, we must maintain the particular chains of habitats upon which different salmon populations depend. Each population must have the right habitat, at the right time, under the right conditions, to perform its essential life functions: spawning, rearing, migrating, feeding and avoiding predators. What's more, these habitats must remain connected so that they can be accessed at the appropriate time. If a particular habitat degrades such that it does not support salmon at the time when the salmon need it, the ecological chain for that population is broken. The salmon may not be able to take an alternate route or "postpone their trip." Instead, that population risks dying out, reducing both the diversity of salmon life histories and the biological diversity within the region.

Restoration Guidelines

1. View the whole picture: Watershed restoration efforts need to be placed within the context of the entire watershed; species recovery efforts must be placed within the context of complete life cycles.
2. Characterize existing conditions and use the results to inform the entire restoration planning process.
3. When planning watershed restoration actions, prioritize and sequence them to maximize long-term success in meeting the stated objectives for the restoration.
4. To the maximum extent practicable, use natural processes to achieve ecological functions and societal goals.

The ecological principles discussed so far have significant implications for the implementation of restoration activities. They are the foundation for the four restoration guidelines, which will guide the City of Portland's watershed restoration efforts.

Viewing the Whole Picture. The restoration guidelines emphasize developing a thorough understanding of a watershed before taking action. This includes understanding (1) the geographical extent of the watershed, (2) the ranges over which species' life histories are carried out, (3) upstream, downstream, lateral and vertical influences throughout the watershed, and (4) hydrology, physical habitat, water quality and biological communities. Any site-specific restoration activity should be understood in terms of its effects and potential for success in relation to the processes and impacts occurring over the entire watershed. Viewing the whole picture also clarifies what outcomes can realistically be expected to result from restoration actions.

The solutions developed to restore a watershed will be appropriate and effective only if the nature and dynamics of the problems that degrade the watershed are clearly understood.

Understanding Existing Conditions. The City of Portland has identified four areas to focus on in evaluating watershed health, both now and after restoration measures have been implemented:

- **Hydrology.** Hydrology affects virtually everything else in a watershed, including the physical form of the stream channel; water temperature and quality; the fate and transport of pollutants; the extent, composition and location of vegetation; material deposited and habitat created in floodplains; and the connectivity of channels and floodplains.
- **Physical habitat.** Physical habitat encompasses both upland and streamside vegetation, logs and large wood debris, substrata such as gravel and sediments, and off-channel areas in floodplains. Restoring such habitats secures a foothold for native species, which are adapted to those particular conditions. In addition, restoring physical habitat improves other measures of river and watershed health, such as stream temperature and nutrient cycling.
- **Water quality.** Aquatic organisms are greatly affected by water quality, including temperature and the amount of dissolved oxygen, nutrients, suspended sediments and contamination. In urban areas, water quality can be degraded by stormwater runoff, sewer overflows, removal of native vegetation, erosion and other factors.
- **Biological communities.** What plant and animal species live in the watershed? Are they native or nonnative? What are their habitats? Who is preying on whom? The presence, abundance and interactions of aquatic, riparian and terrestrial species give a picture of overall watershed health.

In each of these four areas, the City of Portland has identified potential environmental indicators that reflect the health of a watershed, such as seasonal patterns of flow, percentage of native vegetation, water temperature and salmonid productivity. For each watershed, a set of environmental indicators will be established, along with a quantitative target value or a descriptive (but measurable) desired condition to be achieved for each indicator. The target value or desired condition is a specific, measurable level at which the indicator is considered to be healthy or functioning well. Human influences (such as the amount of impervious surfaces) and landscape factors (climate, soil type, gradient and the like) also will be considered as the City determines how existing conditions are affecting watershed health.

The Importance of Order. For greatest success, restoration actions must be prioritized in terms of effectiveness, need and effect on future projects. Then they must be implemented in a sequence consistent with the principles already discussed. For example, it does not make sense to reintroduce native fish stocks until functioning habitat has been established. This, in turn, depends on having more normalized river flows. The scientific principles, then, point to the following as a sensible order for restoration efforts:

1. **Protect existing fish and wildlife populations and their habitats.** Rebuilding an existing population is far more likely to be successful than reintroducing a population that has been greatly reduced. Genetically, because existing populations are adapted to local conditions, they may have better long-term survival rates than introduced populations would. Also, existing populations point to habitat that provides at least the minimum level of ecological functions needed for survival. Similarly, protecting existing functioning habitat and areas that have close to normative hydrology and good water quality should be a high priority.

In the long run, it is easier and more effective to protect existing functioning habitats than it is to create new ones.

2. **Reconnect favorable habitats.** This allows existing populations to provide "colonists" that can reestablish satellite populations in nearby habitat where populations have been extirpated.
3. **Identify and control sources of degradation.** Causes of degradation should be identified and quantified before their impacts within the watershed are addressed. Without sufficient understanding of the processes that are causing an environmental problem, the most important causes may not be addressed and the "solutions" may be misapplied or inappropriately designed. In other words, it is important to get to the source of the problem, rather than merely focus on actions that address symptoms.
4. **Restore the processes that maintain watershed health.**
   - **Normalize hydrology.** Hydrology is one of the most basic and critical forces shaping the structure and function of river and wetland ecosystems. While full restoration of hydrologic conditions may not be possible because of changes in the watershed, the degree to which hydrology is restored will affect all other processes and components of the ecosystem.
   - **Restore physical habitat.** The City of Portland recommends that existing high-quality habitat be protected and made accessible to migratory species, that intermediate-quality habitat be evaluated for restoration and that low-quality habitat be evaluated to determine whether it is impeding access to higher quality habitat. Restoring physical habitat to conditions to which native species have adapted over evolutionary time is key in reducing the dominance of invasive species.
   - **Improve water quality.** Many aspects of water quality will be greatly improved by controlling sources and restoring hydrology and physical habitat. Further efforts

should focus on aspects of water quality not fully addressed by restoring hydrology and physical habitat, such as toxic contamination.

– **Reestablish biological communities.** To a degree, biological communities will be reestablished as a consequence of other protection and restoration efforts (that is, protecting existing populations, improving conditions and connections among habitats, controlling sources of degradation, etc.).

Making Use of Natural Processes. The ecological principles make it clear that, to be successful over the long term, restoration must focus on reestablishing normal ecological processes and functions in watersheds, rather than rely solely on technological solutions to ecosystem problems. Too often, technological "solutions" turn out to be expensive failures, for multiple reasons. They may reflect an incomplete understanding of the existing conditions and processes, be implemented at the wrong scale for the problem they are trying to solve, be designed to operate counter to ecological or biological processes, or address only the symptoms of environmental degradation, rather than its causes.

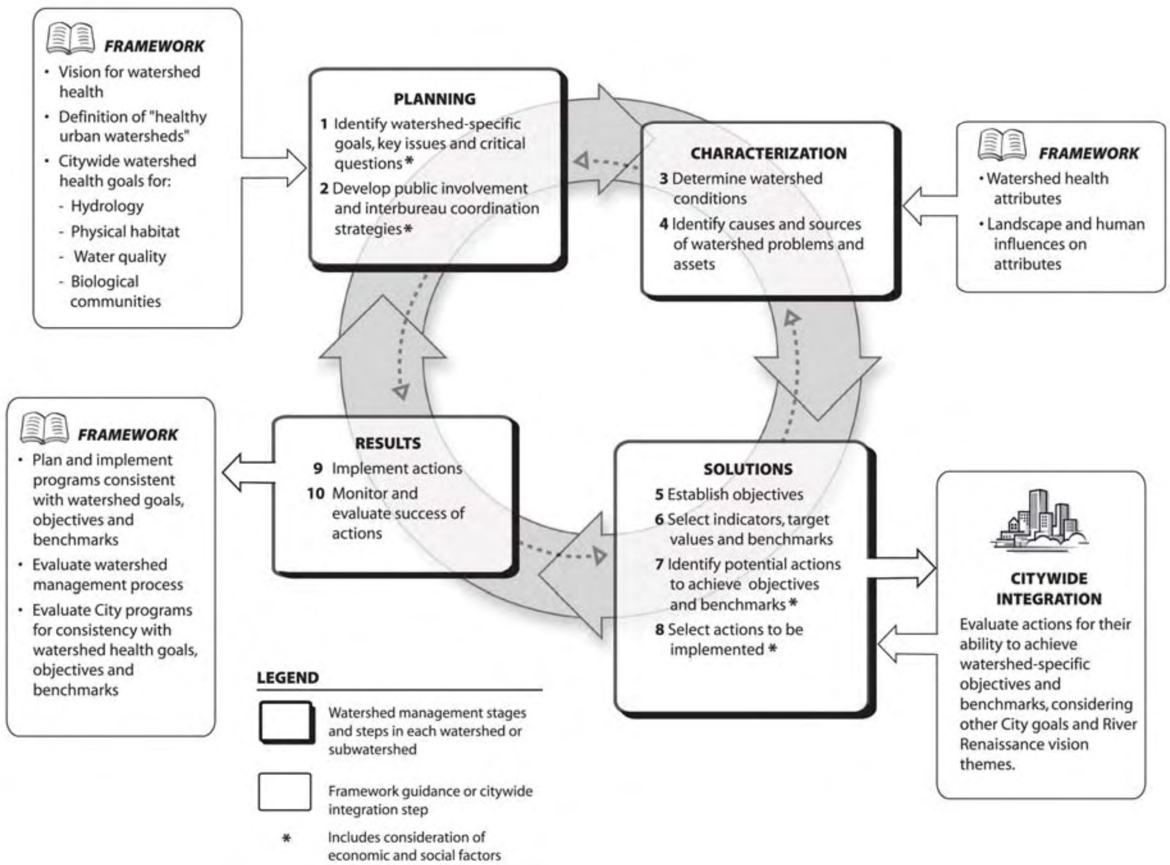
Consider, for example, the 70 years of traditional flood control approaches in Johnson Creek, which have been ecologically detrimental to the watershed, without controlling floods. As an alternative to flood "control," the City of Portland has instituted flood management measures that provide room for the creek to flood. This puts nature to work in reestablishing normal hydrologic processes and habitats, while still preserving human safety and property. Flood management measures include purchasing properties within the floodplain from willing sellers, demolishing structures and removing fill. As a result, floodplains are being reconnected, flood storage is being reestablished in the watershed and off-channel fish and wildlife habitat is being created.

Natural processes are generally far more effective and cheaper than the technological processes designed to replace them. Wherever possible, restoration plans should make use of natural processes.

Even at their best, technological solutions cannot replace the functions provided by habitats and species that have evolved together over millennia to create diverse, resilient, productive ecosystems. Simply put, the cost and effectiveness of natural processes are hard to beat.

Restoration in a City Setting. Native species—both endangered and not—have a reasonable chance of survival with the right hydrology, the right habitats, adequate water quality and biological diversity. With these elements functioning properly, the ecosystem itself is likely to become more diverse, complex, resilient and self-sustaining as time goes on. Portland's rivers, streams and creeks in many places are arguably in better condition now than during the mid-twentieth century, demonstrating that improvements to watersheds are possible even in a thriving urban area.

FIGURE 3-1
Stages and Steps in the Watershed Management Process



CHAPTER 3

Managing Portland's Watersheds

Successful watershed management requires actions that focus on improving the health of watersheds, plus a way of ensuring that City activities not directly related to watersheds are nonetheless consistent with the scientific principles and watershed health goals and objectives. The *Framework* addresses both these aspects of watershed management. Although the steps presented below will be used to develop watershed plans, they can be applied to other City activities, including planning new projects, such as urban renewal and transportation projects. The steps also will guide day-to-day City activities and decisions.

The Watershed Management Process

The City of Portland's watershed management process translates the watershed health goals, scientific principles and restoration guidelines into a set of prioritized watershed protection and restoration actions for each of Portland's urban watersheds. The process has four stages:

- **Planning**. Goals, key issues (including social and economic factors) and coordination and public involvement strategies are identified for each watershed.
- **Characterization**. A detailed "snapshot" of current watershed conditions is created and, when possible, compared to historical conditions. Both watershed problems and healthy, properly functioning watershed conditions are identified, as are their sources or causes.
- **Solutions**. Potential protection and restoration actions are identified and analyzed. A preferred set of actions is recommended that incorporates City aspirations not directly related to watershed health.
- **Results**. Actions are implemented and their effects are monitored. Through adaptive management, the actions are adjusted as their impacts become clear, as scientific understanding of watershed functions increases and as techniques for watershed restoration improve over time.

The watershed management process will result in a watershed management plan for each watershed. The plans will lay out activities necessary to achieve watershed health, such as on-the-ground capital improvement projects or habitat improvement projects, and will guide other City activities so that they are compatible with the watershed health goals.

Figure 3-1 shows the individual steps within these four stages. The figure conveys the iterative, continuous nature of the watershed management process, as protection and restoration actions are refined in response to information gained from ongoing monitoring. The steps in the process are described below.

Step 1: Identify watershed-specific goals, key issues and critical questions.

All four of the watershed health goals apply in each watershed. However, because each watershed has its own characteristics and watershed health issues, they may be supplemented by goals that address other City concerns, such as public health and safety.

Key issues and questions about each watershed will be identified, to provide guidance throughout the watershed management process. Many of the critical questions will be about hydrology, physical habitat, water quality and biological communities: What are the flow conditions, flooding patterns, habitat types, ecological functions, species and pollutants in the watershed? How are they distributed? What affects them?

Other questions will address such issues as public health and safety, economic factors, public involvement and coordination within the City as those issues relate to watershed health.

Step 2: Develop stakeholder, public involvement and interbureau communication and coordination strategies.

Success of the watershed management process will rely in part on shared understanding, consensus and cooperation among those whose actions affect watershed health—namely, stakeholders and the public, various City bureaus and programs, and other jurisdictions in the Willamette and Columbia River basins. Step 2 entails identifying ways for the public to help shape watershed-related decisions (including the social and economic aspects of watershed management), involving staff from multiple City bureaus in the development of the watershed management plans, clarifying relevant roles and responsibilities within the City and coordinating the watershed restoration efforts of Portland and other entities in the region. Detailed work plans will document activities, procedures, responsibilities and resources related to the work to be done in each watershed.

Step 3: Determine watershed conditions.

Describing Watershed Conditions. The first step in the watershed characterization stage involves describing watershed health attributes, such as water temperature and the condition of the streambank, to understand the current (and sometimes historical) conditions and ecological functions in the watershed. Of particular value is understanding which areas have ecological problems (and therefore may need restoration activities) and which areas are functioning well. In the *Framework*, healthy, properly functioning conditions are considered watershed assets, potentially deserving protection.

A watershed characterization is a snapshot of how the watershed functions today and will continue to function in the near term.

Watershed health attributes are discrete, measurable components of the ecosystem. Together, they paint a picture of the ecosystem's overall health and reveal which ecological functions it currently provides. Table 3-1 shows the watershed health attributes the City of Portland will focus on during characterization of each watershed.

The City also will examine the factors that influence the watershed health attributes—primarily various human activities and characteristics of the landscape (see Table 3-2). For example, in a given watershed, landscape factors such as the steepness of the hillside, soil type and rainfall pattern all may affect the amount of sediments that enter a stream, as do human activities such as channel and wetland alterations. Identifying landscape factors and human influences helps define the potential and limitations of particular stream reaches.

TABLE 3-1
Watershed Health Attributes to Be Characterized

Hydrology	Water Quality
Hydrograph alteration Floodplain presence and connectivity Groundwater	Water temperature Dissolved oxygen Nutrients and chlorophyll *a* Total suspended solids Toxic contamination of water, sediments and biota Groundwater quality Other 303(d)-listed TMDL parameters Other parameters (as determined by weight of evidence)
Physical Habitat	**Biological Communities**
Floodplain quality and connectivity Riparian condition: width, composition and fragmentation Stream connectivity Habitat types Bank erosion Channel substrate (fine/coarse) Refugia (depth, boulders, undercut banks, wood) Large wood Terrestrial habitat Wetland habitat	Biotic integrity Benthic communities Salmonid population structure (abundance, productivity, spatial structure, diversity) Riparian wildlife Terrestrial wildlife Plant communities

TABLE 3-2
Factors That Influence Watershed Health Attributes

Landscape Factors	Human Influences
Climate	Land use
Physiography	Impervious surfaces
Lithology/soils	Dam impacts
Watershed morphology	Water withdrawals
Hydrology	Drainage network
Vegetation	Vegetation management
	Wetland alteration
	Outfall discharges
	Exotic species
	Harassment
	Hatchery management
	Spills and illicit discharges

Existing data about current and (where available) historical watershed conditions will be compiled, and any information that is still needed will be identified. Relevant information could include rainfall data, monitoring data for flow and water quality, stream survey results and aerial photographs or geographic information system (GIS) data on land use. Information will be stored in a GIS-based data management system that can generate base maps and overlays.

The watershed characterization will build on existing information as much as possible.

Additional data will be collected as needed. In some cases the compiled data will be used to model current watershed conditions. For example, state-of-the-art hydrologic, water quality and habitat models will show (1) the impacts of stormwater runoff, waterborne pollutants and habitat conditions on different species, and (2) how those impacts occur.

Reference conditions are determined by reviewing historical information, data from similar but less disturbed areas, scientific literature and regulatory standards.

Identifying Problems and Watershed Assets. The City of Portland will identify watershed problems and assets in part by using the compiled data and modeling results to compare current watershed conditions with reference conditions. (Reference conditions reflect the watershed's condition if all of its environmental attributes were functioning properly.) The point of such a comparison is to see where and how far existing conditions diverge from the reference conditions. This will reveal both problem areas in the watershed and opportunities to protect existing watershed assets.

For example, a comparison of current watershed conditions and reference conditions might reveal that, toward the mouth of a particular stream, there currently is an excess of fine sediment during the winter—too much for salmon rearing. Or the comparison could show that habitat along the entire stream is unsuitable for salmon fry emerging from gravel in the spring, but that at other times the stream could support salmon relatively well. This highlights existing watershed conditions during most of the year that, if maintained, could help sustain important species and habitats.

Because many river and stream reaches already provide good, healthy habitat or other important ecological functions, the watershed management process will identify opportunities to protect and maintain existing functioning conditions.

One of the models the City will use in identifying watershed problems and assets is Ecosystem Diagnosis and Treatment, or EDT, which among other things can compare the relative ecological contributions of different stream segments. In other words, EDT can predict the ecological benefit that individual reaches would provide if they were restored—or the ecological loss if they were allowed to degrade. This is useful in prioritizing protection and restoration actions.

Step 4: Identify the causes, sources and effects of watershed problems and assets.

It is not enough merely to understand what problems exist in a watershed and then devise possible solutions. For restoration actions to be successful, the underlying causes and sources of a problem also must be identified. Without this crucial step, restoration actions might address only the symptoms of the problem, without solving the problem itself. Likewise, if a watershed asset is going to continue into the future, the underlying reasons for its existence must be understood. That way, the conditions that create the asset can be maintained rather than inadvertently disrupted (to the detriment of the asset).

For example, a stream reach might not have enough gravel to support spawning. This could be the result of (1) excessive sedimentation, (2) an upstream barrier that "starves" the reach of gravel, or (3) changes in hydrology that prevent gravel from being deposited in the reach. Although there are three possible solutions to the problem, only one of them may be effective, depending on the underlying cause and source. Similarly, an asset such as cool summer water temperatures might be the result of (1) deep pools in the stream, (2) shade from native streamside vegetation, (3) inflow of groundwater, or (4) a combination of these.

Step 4, then, focuses on understanding the processes that create a given problem or asset in a watershed. To tease out the cause-and-effect links, the City may use a variety of hydrologic and pollutant models to answer the following questions for each identified watershed problem or asset:

- What resource is being affected, and where?
- What watershed processes, pollutants or materials (sediments, nutrients, heat, etc.) are involved?
- What mechanism is causing the effect, and what activities trigger or contribute to the effect? (An example might be a storm that increases runoff and thus causes erosion.)
- What physical features are present that provide critical habitat for fish or wildlife species or populations?

Correctly identifying the cause and source of a problem is key in determining an effective solution.

For example, Steps 3 and 4 might reveal that excessive sediment is being deposited in lower Balch Creek as a result of bank erosion, which in turn is caused by increased flows and inadequate bank vegetation. The high flows come from stormwater discharged into the stream via stormwater drainage pipes.. The effects of the sedimentation are a decrease in the amount of usable spawning area, smothering of trout eggs and, ultimately, fewer trout.

Step 5: Establish watershed-specific objectives.

Once the source-cause-effect links that clarify the origins of watershed problems and assets are understood, the City can start setting objectives to reach its goals and take other steps that lead to restoration or protection actions. This "solutions" stage of the watershed management process begins with establishing objectives.

Objectives state specific desired outcomes with respect to certain ecological functions or conditions—outcomes that must be achieved for a watershed health goal to be attained.

Good objectives

… consider the cause-effect relationships underlying watershed problems or assets.

… are specific.

… are measurable.

… describe the desired outcome for a particular resource.

Using the example above, an objective can be established as follows:

- Problem: Sediment deposition on the substrate of Balch Creek.
- Cause: Erosion resulting from high flows and lack of bank vegetation.
- Source of high flows: Stormwater runoff discharge from stormwater drainage pipes.
- Effect: Limited spawning area, smothering of eggs and reduced trout production.
- Desired outcome: Reduced sedimentation and increased trout production.
- Objective: Reduce erosion-caused sedimentation in the channel substrate, to enhance cutthroat trout spawner and juvenile production in lower Balch Creek.

This objective expresses the problem, something about its cause, and the desired outcome. Later in the watershed management process the objective can be refined to specify one or more measurable environmental indicators, a geographical area and a time frame, as follows:

- **Refined objective:** Reduce streambed fine sediment embeddedness to 20 percent or less in lower Balch Creek by 2040 to support cutthroat trout spawning and egg incubation.

Step 6: Select indicators and establish target values and benchmarks.

Environmental Indicators. What is really important about watersheds is the ecological functions they provide, such as the cycling of nutrients and energy. Essentially, ecological functions are what truly define watershed health, for it is only when a full suite of functions is provided that watershed conditions support the diversity of healthy, self-sustaining populations of native fish and wildlife that is considered representative of a healthy watershed.

Ecological functions are the ultimate measure of watershed health, but they are often impractical or impossible to measure directly.

It is often impractical and sometimes impossible to measure ecological functions directly. Instead, scientists typically measure environmental indicators that, taken together, represent the ecological functions provided by an ecosystem. It is easier, for example, to measure the width, vegetative composition and connectivity of a streamside area than it is to quantify the water quality, microclimates, food and structural habitat such an area provides.

Environmental indicators must be selected carefully, so that they are objective, readily measurable and comprehensive. They also should convey an understanding of how the ecosystem functions and provide insight into the cause-and-effect relationships between stressors to the ecosystem and how the ecosystem responds to those stressors.

From Goals to Actions

Watershed health goals
↓
Objectives
↓
Environmental indicators
↓
Reference conditions
↓
Target values
↓
Benchmarks
↓
Restoration and protection actions

As a way of measuring watershed health over time, the City of Portland will select and monitor a unique set of environmental indicators for each watershed—one that reflects that watershed's conditions, problems and assets. The indicators will be selected from the watershed health attributes and human influences in Tables 3-1 and 3-2; these are based in part on indicators developed by the National Marine Fisheries Service in the National Oceanic and Atmospheric Administration (referred to as NOAA Fisheries).

How Will the City Know When a Watershed Is Healthy? The City will be taking actions to improve ecological functions, and the indicators will be used to determine whether these functions are improving. For example, the City will be reducing pollutant loads, cooling stream water and providing off-channel fish habitat. But how will the City know how much to cut pollutants, how cool is cool enough and when sufficient habitat has been restored? In other words, what functions or conditions would be present if the watershed were healthy, and where in the watershed should they be occurring?

To answer this question, the City will consider the reference conditions for each watershed when setting target values for each indicator. A reference condition is the ideal condition for an indicator in a particular watershed, subwatershed or even stream reach, given the unique physical conditions and constraints at that location. Target values represent desired conditions, taking the reference conditions into account but also being realistic about the constraints posed by the urban environment. In other words, target values acknowledge aspects of the environment that are unlikely to change, such as the fact that a city will continue to have roads and buildings. Essentially, target values define a level of ecological functioning in an urban setting that the City of Portland will strive to reach in order to achieve its watershed health goals and objectives.

Target values reflect both the watershed's potential and the constraints posed by its surrounding urban environment.

Deciding on appropriate target values is difficult because healthy ecosystems are always changing. Even pristine and fully functioning ecosystems have areas that, considered in isolation, would seem unhealthy. The challenge is to set a single value that accommodates the natural variation in ecosystems—from one location to another and through time, as ecosystems are disturbed and then recover, thereby creating new habitats and a more complex (and stable) system. One solution to this problem is, for each indicator, to establish a range of acceptable values.

What seems unattainable now may become attainable over time, and what seems easily attainable now may prove more difficult than expected.

Measuring Progress. To measure progress in achieving objectives—and ultimately the watershed health goals—the City will set benchmarks for each indicator. The benchmarks will state specific values to be reached in particular watersheds, at particular points in time, as the City moves toward the target values. Benchmarks will reflect the physical, biological, social and institutional factors that affect the rate of progress. Such factors include funding limitations, the need to protect human health and safety, and the fact that some projects are already under way.

Objectives, target values and benchmarks all will be refined as new information becomes available.

The relationship among reference conditions, current (baseline) conditions, target values and benchmarks is shown in Figure 3-2. In reality, benchmarks may not follow a linear path as depicted in Figure 3-2. For example, it could take 50 years for trees planted now to provide sufficient shade to have a cooling effect on water temperature.

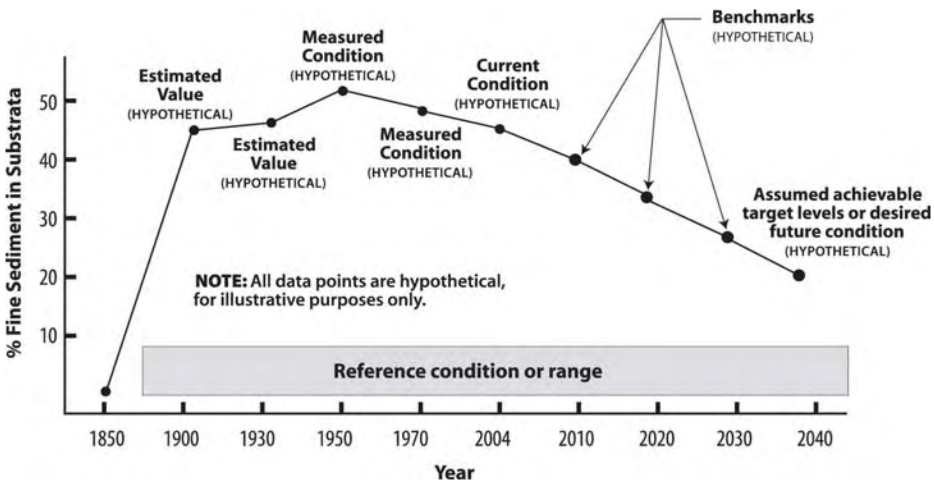


FIGURE 3-2
The Use of Reference Conditions, Target Values and Benchmarks

Step 7: Identify, evaluate and prioritize actions to achieve watershed health objectives and benchmarks.

In this step, a "long list" of potential watershed actions will be developed, and the actions will be screened to create a "short list" that will be evaluated further in Step 8.

Generating the Long List. Potential actions will be identified by reviewing scientific literature, considering the results of the watershed characterization, conducting inventories of ongoing and planned actions, and consulting with stakeholders who already are working in the watersheds. Likely types of potential actions include on-the-ground projects that require capital expenditures, modifications to ordinances or codes that affect watershed conditions and processes, and nonregulatory programs or initiatives such as education and conservation easements.

Potential actions could include nonregulatory measures (such as conservation easements, land acquisition, erosion control, pollutant source reduction, water quality treatment, septic system management, or the protection or restoration of instream habitat, stream-banks, wetlands and terrestrial habitats) or regulatory measures (overlay zoning, for example).

Checking Against the Restoration Guidelines. The potential actions then will be analyzed in terms of how well they align with the restoration guidelines. Priorities will be roughly as follows:

1. Existing high-quality habitat and properly functioning watershed processes
2. Connections among healthy habitat areas
3. Source control
4. Stream flow and hydrology
5. Physical habitat
6. Water quality
7. Biological communities

Actions that deal with the most fundamental aspects of restoration—and thus are likely to have the greatest impact—will be considered most favorably. Also highly valued will be actions that deal with more than one system or restoration element at once.

Screening for Implementability. Potential actions will be screened for general cost and technical feasibility. How effective will the action be? How much will it cost? Will it conflict with other priorities, either public or private? Is it likely to be supported by regulators? By the community? Asking such questions will help separate those actions that are clear "winners" from those that currently are infeasible, inordinately expensive or socially unacceptable; the latter will not be considered further at this time.

Grouping. The remaining "short list" of potential actions will be sorted into logical groupings based on the type of watershed objective, problem and solution. Organizing potential actions this way will help in determining whether a single action could address multiple problems (an example would be planting streamside vegetation to both improve water temperature and stabilize eroding streambanks). Conversely, multiple actions might best be grouped together because they all are needed to achieve a single objective (for example, several erosion and sediment control actions might be grouped together because they all improve water quality). Of particular interest will be actions that address more than one watershed process at a time and thus offer multiple—and perhaps far-reaching—benefits. Modeling tools will be used to help determine the relative effectiveness of various sets of actions.

Projects that address multiple problems or affect several watershed processes at once will likely make the "short list" of potential actions.

Step 8: Select the set of actions to be implemented.

The analysis, screening and grouping in Step 7 will result in several alternatives (that is, sets of potential actions), all of which would achieve the City's watershed health goals, albeit in different ways. In Step 8, a set of actions is selected for each watershed, taking into consideration social and economic factors and other nontechnical values.

Structured Decision Making. To assess the relative merits of the different sets of actions, the City of Portland may use a structured decision-making tool, such as multi-attribute analysis software. Typically, such a tool analyzes each alternative using evaluation factors that reflect the City's watershed health values (protecting high-quality habitats, maximizing habitat access and connectivity, etc.). For each evaluation factor, each alternative receives a numerical score that expresses how well that alternative would achieve the values reflected in the evaluation factor. In addition, the various evaluation factors are weighted according to importance. The scores and weightings are then used to generate a total score for each alternative. These total scores provide a means of comparing the different alternatives.

Although structured decision making may seem complicated or mechanistic, it has many advantages, especially when the "easy" decisions have already been made, the alternatives reflect competing values and disparate benefits need to be compared. It provides objective information about the merits of different alternatives and a means of documenting the decision-making process.

Incorporating Other City Values. The watershed management process will generate accurate, scientifically based information and recommendations about possible actions that would achieve the City's watershed health goals, objectives and benchmarks. However, the scientific information must be considered within the larger context of decision making at the City of Portland—a context that includes public debate, other City goals (such as public safety, neighborhood livability and aesthetics) and the financial impact of particular policy decisions.

Cost, regional issues, public input, City values not directly related to watersheds, such as economic viability and transportation—all will play a role in the City's decisions about watershed management.

These other values must be considered before a final set of actions is selected. To ensure that City values not directly related to watersheds are incorporated into the watershed management process, the City may use a multi-objective decision-making methodology similar to the multi-attribute analysis software just discussed. Such a methodology would help clarify the socioeconomic and environmental impacts of various restoration options as the City decides what level of commitment it wants to make to achieve watershed and river health. The City may also use a cost-benefit analysis that, among other things, pinpoints the ecosystem services (water purification, precipitation interception, etc.) provided by each alternative and the dollar value (compliance costs avoided, reduced flood damage costs, etc.) associated with each of those services.

Completing the Watershed Management Plan and Other Plans. At the conclusion of this step, the City of Portland will produce—for each watershed—a watershed management plan and related documents that lay out the recommended set of actions for achieving watershed health goals, objectives and benchmarks. Additional plans or documents may be needed to comply with regional, state and federal regulations. For example, these plans could include a water quality management plan, a habitat conservation plan or amendments to the City's Comprehensive Plan.

Step 9: Implement the selected set of actions.

Implementation will involve the following:

- Sequencing protection and restoration actions based on the severity of the environmental problems, the effectiveness of the actions, the restoration guidelines, technical feasibility, cost, regional considerations and other City goals, plans and fiscal priorities
- Identifying bureaus and programs that will be responsible for ensuring that actions are designed and implemented properly, funds are secured and spent appropriately, implementation proceeds on schedule and public education about the actions takes place
- Identifying capital improvement projects that may affect watersheds, rivers or biological communities and determining whether those projects require more formal consultations with regulatory agencies

- When necessary (such as when a change in the zoning code is recommended), conducting additional public involvement and following City Council approval procedures

Step 10: Monitor and evaluate the success of actions.

Because scientific understanding of watersheds is incomplete, the City of Portland will not be able to predict the effects of its watershed actions with certainty. Yet the City cannot afford to wait until scientific knowledge is complete. Instead, the City will proceed by documenting its assumptions about watershed ecology and processes in the watershed management plans and then implementing the recommended actions.

Adaptive management provides a way for the City to continually update its understanding of and assumptions about watershed processes so that they are more accurate and can point to more effective solutions to watershed problems.

The watershed management plans are not the be-all and end-all for watershed management in Portland, and Step 10 of the watershed management process reflects this. Step 10 involves monitoring and adaptive management. Adaptive management is a dynamic process of improving management activities incrementally as decision makers learn from the results of actions that have been implemented and as better information and analytical tools become available. In other words, the effect of adaptive management is to gradually improve protection and restoration approaches over time. Adaptive management involves checking progress made in achieving watershed goals; adjusting actions, benchmarks, targets and objectives accordingly; rechecking; and readjusting—all the while incorporating new data and scientific knowledge.

Making Adaptive Management Work. For an adaptive management program to be successful, it must have the following:

- Clear, measurable objectives against which to measure success in achieving watershed and river health goals
- Benchmarks linked to timelines, to map out the desired rate of progress in achieving the objectives
- A monitoring program to determine how well actions have been implemented, detect changes in environmental conditions, and check progress in achieving the benchmarks and target values
- Regular review of the monitoring data, comparison of the data with the benchmark or target values, and a method of adjusting actions in response to this comparison

Monitoring data must be compared to the benchmarks and target values on a regular basis to determine what progress is being made and whether actions need to be changed.

The City will lay out these elements of adaptive management in the watershed management plans. In addition, on a regular basis it will compare monitoring data to the benchmark and target values and adjust actions accordingly. Periodically, the City will analyze the monitoring results in depth and their implications.

Depending on the results of the monitoring, Step 10 of the watershed management process could involve the following:

- Collecting additional information where there are data gaps and uncertainty
- Updating the scientific foundation, assumptions about watershed processes and indicators that underlie the watershed management process
- Revising objectives to reflect the most current scientific information
- Adjusting targets and benchmarks in light of new information
- Refining the models used in the characterization and solutions stages
- Improving or replacing ineffective solutions

The Role of Monitoring. Monitoring is an essential element of adaptive management. A monitoring program that answers the following questions will be developed for each watershed:

- Have the actions been carried out as planned?
- Are the actions functional and working?
- Are the actions having the intended effect?
- Are the actions helping to achieve the benchmark values, the objectives and the City's ultimate goals for watershed health?

As much as possible, the monitoring needed for Step 10 will build on existing City monitoring programs. In some instances, new monitoring projects may be required.

Ensuring That City Projects Are Compatible with Watershed Health Goals

Although the watershed management plans generated through the watershed management process will provide valuable guidance, the City will not achieve its watershed health goals simply by implementing the protection and restoration actions called for in the watershed management plans. Additional guidance will be needed, and the City must have processes for ensuring that all City projects are as compatible as possible with the watershed health goals. These processes will apply to transportation plans, capital improvement projects, urban renewal activities, land use reviews and other City activities that do not in and of themselves focus on watersheds but that have the potential to affect watershed health.

Compatibility Process for Major New Projects and Programs. As major new projects and programs are developed at the City of Portland, they should be planned and designed to be as consistent as possible with the scientific principles, restoration guidelines and watershed health goals in the *Framework* and with the relevant watershed plan. Briefly, a process for ensuring compatibility will involve the following:

- Identifying any relevant watershed goals, objectives and benchmarks early in the project planning process; determining how the proposed project can help achieve those goals, objectives and benchmarks; and setting appropriate project goals that reflect watershed health goals

- Planning the project to include coordination with City programs that are involved in watershed health management
- Incorporating relevant watershed-related policies and recommendations into the project
- Modeling the project's positive and negative effects on watershed health and, as needed, either redesigning the project or identifying mitigation measures to achieve project watershed goals
- Monitoring the project using adaptive management

Regular Review of All City Programs. To ensure—to the greatest extent possible—that City programs, plans, projects and practices do not adversely affect watershed health, and that they are as consistent as possible with the watershed management plans and goals, City bureaus periodically may be asked to report to the City Council on the compatibility of their programs and activities with the City's watershed health goals. In brief, the bureaus would do the following:

- Identify programs and activities that could affect watershed health.
- Evaluate each program or activity in terms of (1) its potential impact on watershed health, (2) ways those impacts can be avoided, reduced or mitigated, and (3) opportunities to enhance watershed health.
- Identify funding and other resources needed to avoid potential impacts and enhance watershed health.

The City's natural resources staff will provide additional guidance in the form of technical memoranda, "how-to" manuals and checklists, day-to-day technical assistance, training sessions, workshops and policy manuals to bureaus whose actions affect watershed health.

These compatibility processes are not intended to be onerous or rigid. Rather, they are ways of periodically checking to see whether the City's bureaus and programs are—overall, and on balance—applying the principles of watershed management to both their everyday activities and their long-range programs. As needed, the City's natural resources staff will aid the bureaus as they go through this process of determining whether their activities are compatible with the City's watershed health goals.

CHAPTER 4

Ongoing Elements of Watershed Management

As explained in Chapter 1, the citizens and government of Portland have a vision for the City that involves a thriving natural river system with clean, healthy urban waterways and watersheds. Such a system would benefit fish, wildlife and—by enhancing Portland's livability, environmental health and economic vitality—people, too. Although the *Framework for Integrated Management of Watershed Health* represents an important step in making this vision a reality, the *Framework* approach is iterative and will necessitate ongoing efforts over the coming decades, including the following:

Applying the scientific principles and guidelines in the *Framework* and following the watershed process it describes will necessitate many ongoing efforts.

- **Addressing existing uncertainties** about species, habitats and water quality conditions in the City's watersheds, and how certain aspects of the ecosystem function in an urban setting. This will involve continuing to study salmonid use of the City's watersheds, studying the distribution and habitat needs of key riparian and terrestrial species, and filling data gaps about ecosystem relationships and functioning.
- **Delineating certain elements of the *Framework*** in more detail, such as specific roles and responsibilities, data management protocols, and processes for evaluating and selecting potential actions, applying adaptive management, and providing guidance on the *Framework* to City staff.
- **Developing a monitoring program to track progress** in achieving the watershed health goals. This is an essential part of adaptive management.
- **Providing appropriate funding** to develop and update the watershed management plans; implement, monitor and evaluate the selected actions; and ensure the compatibility of City projects with the watershed health goals.
- **Involving stakeholders and others** in the watershed management process. The City will need to engage the public, agencies and stakeholders in both policy-level and project-level decisions about watershed health in Portland. To ensure the scientific soundness of the watershed-related documents the City generates, the City should seek review of its work by (1) its Watershed Science Advisory Group, and (2) scientists who can provide independent peer reviews.
- **Providing regional coordination and leadership** in addressing watershed health issues. This includes continuing to build relationships with entities throughout the region; coordinating with regional, state and federal agencies to share the City's scientific information and approach and make sure that the City's approach is in step with their work. Forging strong public and private partnerships at the local and state levels also is vital to success.

- **Addressing the tough issues**. It is likely that following the processes in the *Framework* will raise fundamental questions about Portland's future and spark communitywide discussion about how urban growth and development in the metropolitan area can best occur while the City strives to achieve its watershed health goals. In addressing these issues, the City will seek solutions that integrate seemingly competing values and that provide the best possible outcome for both citizens and natural resources.

Appendixes

The main body of the *Framework for Integrated Management of Watershed Health* is supplemented by technical appendixes that provide background information related to the City of Portland's watershed management approach:

- Appendix A: Presents the City's River Renaissance vision for Portland's future and strategies for achieving the vision.
- Appendix B: Summarizes the federal, state, regional and City regulations that most directly affect the City's approach to watershed management. These regulations include the Clean Water Act (encompasses stormwater and wastewater discharges and pollutant load limits), the Endangered Species Act, the Safe Drinking Water Act, Superfund/CERCLA (including natural resources damage assessment), Oregon's statewide planning goals and guidelines, Titles 3 and 13 of Metro's *Urban Growth Management Functional Plan*, and the City's Environmental Overlay Zone and Greenway Overlay Zone regulations.
- Appendix C: Lists watershed-related activities the City already is conducting that the *Framework* builds upon.
- Appendix D: Describes how the City is coordinating its watershed-related activities with those of entities throughout the region.
- Appendix E: Describes Portland's natural environment, particularly its watersheds, habitats and biological communities.
- Appendix F: Presents NOAA Fisheries' population performance measures for salmonids and its guidelines for setting salmonid population goals.
- Appendix G: Details considerations in selecting indicators of watershed health and presents a comprehensive set of suggested indicators for potential use in the City's watershed management process.
- Appendix H: Describes some of the technical methods and analytical tools the City will use during the watershed management process. These include data collection efforts, the habitat model Ecosystem Diagnosis and Treatment (EDT), integrated hydrologic and water quality models, the Habitat Equivalency Analysis (HEA) and net environmental benefit analysis (NEBA) techniques for comparing the costs and benefits of different resource management alternatives, GIS for spatial analysis, multi-attribute analysis software for decision making and an environmental management system to help plan, implement and track restoration and protection activities.

The *Framework* also contains a glossary of terms and an extensive Literature Cited section.

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CHAPTER 1

Introduction

What Is the *Framework*?

This *Framework for Integrated Management of Watershed Health* describes how the City of Portland intends to achieve and maintain healthy conditions and ecological functions in its urban watersheds—specifically, the areas draining into the lower Willamette River[1], the Columbia Slough, the parts of the Columbia River that are within the City's jurisdiction, Johnson Creek, Fanno Creek, Tryon Creek, and Balch Creek and other tributaries (see Figure 1-1).[2]

This *Framework* describes how the City of Portland intends to achieve and maintain healthy conditions and functions in its urban watersheds.

This *Framework*, whose concept the Portland City Council endorsed in June 2001, presents the following:

- A citywide vision and goals for achieving and maintaining healthy urban watersheds, rivers and streams (Chapter 1)
- Scientific principles and restoration guidelines that serve as the foundation for achieving and maintaining healthy watersheds (Chapter 2)
- A watershed management process (Chapter 3) that involves the following:
  - Characterizing watershed conditions
  - Establishing measurable objectives and benchmarks for achieving watershed health goals
  - Analyzing, selecting, prioritizing and implementing protection and restoration actions[3]

What is a watershed?

A watershed is a geographic area that includes a river or stream, its tributaries and the lands they drain.

[1] Geographically the lower Willamette extends from Willamette Falls to the river's confluence with the Columbia River, but the City of Portland has jurisdiction in the Willamette watershed only from approximately the Sellwood Bridge to the Columbia.

[2] The City of Portland is developing a habitat conservation plan (HCP) to address watershed health issues and Endangered Species Act (ESA) compliance for the City's actions in the Bull Run/Sandy River watershed. The process of developing this HCP is separate from the process described in the *Framework* because the issues, impacts, stakeholders and geographic area are significantly different from those in the City of Portland's urban and urbanizing watersheds. However, the relevant science and technical approach are similar.

[3] It is assumed that protection and restoration actions will take many forms, such as management of stormwater runoff, control of non-stormwater discharges, changes in site designs, land acquisition and zoning, removal of nonnative plant species, fencing to exclude predators of native biota, and public outreach and education. Table 3-4 provides specific examples of potential protection and restoration actions.

   – Monitoring actions to determine progress in achieving goals, objectives and benchmarks

- Processes for ensuring, to the extent possible, that all City projects and activities are planned and conducted in ways that are compatible with watershed health goals (Chapter 3)
- Ongoing elements of watershed management, including additional scientific, policy or procedural steps needed to achieve watershed health goals (Chapter 4)
- Additional information about the regional context for the City's actions, applicable regulations, the City's natural environment, salmonid (salmon and trout) population goals, indicators of watershed health, and some of the technical methods and analytical tools that will be used during the watershed management process (Appendixes A through H)

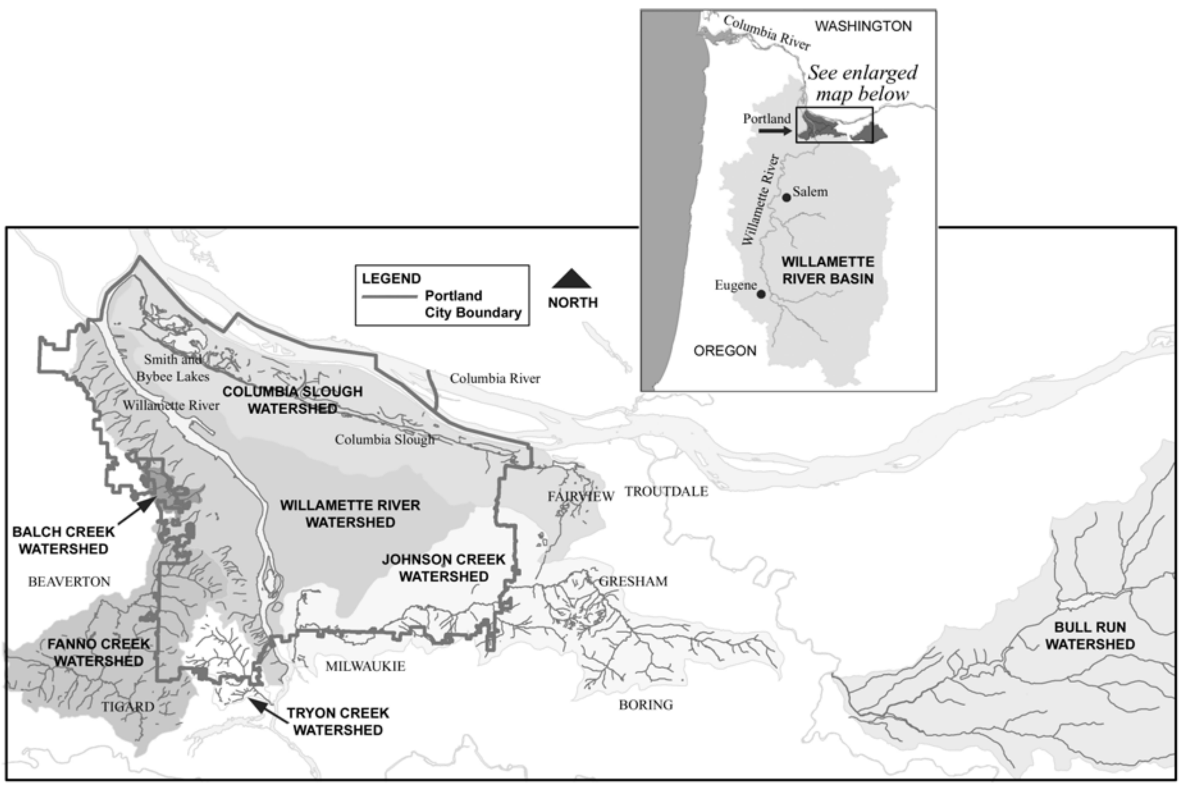

FIGURE 1-1
City of Portland Watersheds

Origins of the Framework

Several factors spurred development of the City of Portland's *Framework for Integrated Management of Watershed Health*:

- **City Council Resolutions.** The Portland City Council adopted several resolutions related to the health of its watersheds. The first (Resolution 35715, in July 1998) states that the

City will "assist with the recovery" of steelhead, a species listed under the federal Endangered Species Act (ESA).[4] Since that time the Council has directed City natural resources staff to assist with the recovery of all ESA-listed salmonids. The second Council resolution (No. 35894, in June 2000) endorses the development of a comprehensive framework to guide the City's integrated response to the ESA, the Clean Water Act and other laws and City objectives. The third resolution (No. 35962, in February 2001) expresses the City's interest in playing a leadership role in determining the cleanup and natural resource restoration strategies for the Willamette River and the Portland Harbor under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or Superfund).[5]

- **The River Renaissance Vision for a Clean and Healthy River.**[6] In March 2001 the City Council adopted Resolution 35978, endorsing a vision for Portland's future that involves revitalizing the Willamette River and its tributaries for the benefit of fish, wildlife and people. The Council's action further recognized the integral role of a clean and healthy river system in the natural, economic, urban and recreational life of the City.
- **Regulatory Requirements.** The City faces the challenges of complying with requirements of the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), the ESA and CERCLA. In addition, Title 3 of Metro's *Urban Growth Management Functional Plan* (Metro 2003) specifically requires implementation of several Oregon statewide land use goals through the avoidance, limitation or mitigation of development's impact on streams, rivers, wetlands and floodplains. By integrating these efforts, the watershed process described in this *Framework* will advance the City's efforts toward compliance with each of these obligations.
- **Regional Subbasin Planning and Salmon Recovery Efforts.** The City of Portland is playing an active role in a number of collaborative regional efforts to restore fish and wildlife and improve water quality and watershed conditions. These efforts include Northwest

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[4] In February 2002, the National Marine Fisheries Service in the National Oceanic and Atmospheric Administration (NOAA Fisheries) announced that it would reconsider its ESA listing determinations for 27 populations (called evolutionarily significant units, or ESUs) of Pacific salmon and steelhead in light of court decisions (67 Code of Federal Regulations [CFR] 6215). In May 2004, NOAA Fisheries announced the release of new proposed listing determinations for the 27 ESUs. These include 13 ESUs of steelhead and salmon that may use or migrate through watercourses in the Portland area. Ten of these 13 ESUs were proposed for listing as threatened: the upper Willamette River, lower Columbia River, Snake River fall-run and Snake River spring/summer-run Chinook salmon (*Oncorhynchus tshawytscha*); the upper Willamette River, lower Columbia River, middle Columbia River and Snake River basin steelhead (*O. mykiss*); the lower Columbia River coho salmon (*O. kisutch*); and the Columbia River chum salmon (*O. keta*). Three of the 13 ESUs are proposed for listing as endangered: the upper Columbia River spring-run Chinook salmon (*O. tshawytscha*), upper Columbia River steelhead (*O. mykiss*) and Snake River sockeye salmon (*O. nerka*). NOAA Fisheries published its final listing designations during June 2005. The ESA listing status for the 13 ESUs of salmon and steelhead found in the Portland area are summarized in Table B-2.

[5] A 1997 study by the Oregon Department of Environmental Quality (DEQ) and U.S. Environmental Protection Agency (EPA) identified elevated levels of some hazardous substances in shallow, near-shore sediments throughout the Portland Harbor. In December 2000, EPA placed the Portland Harbor Superfund site on the National Priorities List of sites requiring cleanup under CERCLA. EPA is overseeing the CERCLA remedial investigation and feasibility study (RI/FS) for the cleanup of Portland Harbor sediment. The RI/FS will include a natural resources damage assessment (NRDA) to determine whether the sediment contamination in the Portland Harbor is found have caused injury to habitat. If so, a restoration plan will be developed.

[6] Having a clean, healthy river is one of five River Renaissance "vision themes." The other vision themes are to maintain and enhance Portland's prosperous working harbor, embrace the Willamette River as Portland's front yard, create vibrant waterfront districts and neighborhoods, and promote partnerships, leadership and education. Together the five vision themes define a direction for Portland's future: to have a vibrant city whose thriving river system links together industry, habitat, business districts and neighborhoods (see Appendix A).

Power and Conservation Council subbasin planning, the Oregon Plan for Salmon and Watersheds, the Willamette Restoration Initiative and coordination with other regional governments and stakeholders on ESA and water quality planning and activities.

- Economic Health. The City of Portland recognizes that healthy, thriving natural systems provide a more sustainable and certain economic base than degraded ones. Healthy natural systems provide valuable ecosystem services, attract skilled labor and entrepreneurs and pass on a legacy of sustainable resource use to future generations—and they help provide these benefits at the best return for the tax dollar. In turn, economic health provides the financial resources necessary to protect, preserve and enhance natural resources. Similarly, responding to multiple and often redundant environmental mandates with independent programs increases costs and delays, reducing Portland's economic competitiveness. An integrated, coordinated approach to environmental regulations and mandates will reduce delays and costs and help retain and recruit business investments.
- Citizen Interest. Individual property owners, neighborhood associations, watershed councils, environmental organizations and others throughout the region have consistently recognized the value of healthy watersheds, rivers and streams in improving community vitality and livability.

A Backdrop of Land and Water

In the Pacific Northwest, rivers and the lands they drain are a living link with the region's history and heritage. They have supported human life for millennia, powered modern economic growth and development and nurtured species such as salmon and Douglas fir that have become icons of our unique region, people and lifestyle. This is especially true in Portland, Oregon, where today—as in the past—the City is defined socially, culturally and economically by the Willamette River, its tributaries and the lands they drain.

Everyone wants rivers to be clean and healthy. For some people, this means having rivers in which people can swim and fish. For others it implies meeting state and federal requirements for human health and safety. And to some, it connotes fully restored and properly functioning aquatic and terrestrial ecosystems. However it is defined, though, a river's health depends on things that happen on land, even miles away.

It is rainfall and the resulting runoff that so closely link land and rivers. Before urban development occurred, the rain that is so characteristic of the Portland area fell through a dense canopy of trees, dripped onto understory vegetation and soaked into the soil, slowly making its way into the river. Even during summer months, when there was little rainfall, cool, clean water in the ground slowly made its way to streams. Today many of the trees are gone, soil is covered by pavement and buildings in major portions of the city, and many streams have been buried or diverted into pipes.

These changes have had many negative environmental effects. Streams and wetlands that once provided habitat for fish and other wildlife no longer exist. Rainwater splashes off roofs instead of vegetation and sheets across parking lots instead of seeping into the ground. It forms urban torrents that run down streets and gulleys, picking up metals, oil and other pollutants along the way. Some of this runoff enters sewers and is cleaned before being discharged into the river. However, runoff often reaches a river or stream untreated, harming fish and wildlife by causing erosion and delivering doses of pollutants. Some pollutants end up in river sediments, while others are transported even farther downstream. During the summer months many streams are denied the infusion of cool, clean water because groundwater levels are low, as a result of reduced recharge.

In Portland, the task of restoring watersheds to healthier conditions is complicated by years of river and watershed degradation, significant alterations in the landscape, disruptions of natural processes, extreme habitat fragmentation, urban growth and seemingly competing goals within the City. In addition, the City has no legal authority over some of the major factors that influence watershed health, such as dams and land uses in other jurisdictions.

There are many things in this picture the City of Portland cannot change. Yet Portland can consciously choose how it develops and how it will influence the health of its watersheds, and it can provide leadership to other entities within the region. The *Framework for Integrated Management of Watershed Health* is a means of doing just that.

A Vision for Healthy Watersheds

An underlying assumption of the *Framework* is that urban areas do not have to contribute to the degradation of clean water or be devoid of native species and thriving natural systems, just because they are urban. In fact, Portlanders repeatedly have stated that they want healthy watersheds, rivers and streams. They recognize that the City does not have to replicate the conditions present when Lewis and Clark traveled through this region in order to have rivers and watersheds that provide clean water, enhance community livability, invigorate the economy, protect human health and support the region's unique biological communities.

The City intends to restore the health of its watersheds for these reasons but also as a way of preserving a legacy for future generations—the natural legacy on which our community originally was built and that in some sense still defines who we are. By altering Portland's urban design, institutional structures and practices in accordance with sound science and with broad public participation, the City seeks to keep the Willamette River and its watersheds the defining features of the community. The City believes that, as the Portland area grows, it will be possible to focus on the root causes of environmental problems instead of their symptoms—to fix problems instead of merely manage them—such that urban activities create a net benefit for the environment and enhance our natural legacy. In addition, improving the health of local rivers and watersheds makes it easier for the City of Portland to meet its obligations under laws, such as the Clean Water Act, the Safe Drinking Water Act, the Endangered Species Act, Superfund, and state and regional land use goals.

Considering citizen values, the contributions that a healthy ecosystem makes to the economy, the River Renaissance vision and legal mandates facing the City of Portland, this *Framework* proposes the following as a vision of the future of Portland's watersheds:

> *Portland's urban form supports both a thriving economy and natural processes that maintain healthy ecosystems. Portland protects and restores properly functioning conditions throughout its watersheds to provide clean water and support abundant, self-sustaining populations of native fish and wildlife. These*

> *efforts enhance the livability and vitality of Portland for its citizens and help meet the City's obligations under the Clean Water Act, the Endangered Species Act, Superfund, the Safe Drinking Water Act and other laws.*[7]

Healthy Watersheds in an Urban Context

Defining Watershed Health in an Urban Area. Given that each watershed (and even subwatershed) is unique, what is healthy in a particular watershed may not be healthy in another watershed. Generally, however, a healthy urban watershed can be defined as follows:

> *A healthy urban watershed has hydrologic, habitat and water quality conditions suitable to protect human health, maintain viable ecological functions and processes, and support self-sustaining populations of native fish and wildlife species whose natural ranges include the Portland area.*

The Natural and Built Environments. Portland's urban setting includes a combination of both natural and built environments. The natural environment includes a host of natural features and processes, such as climate, soils, water, physical habitat and biological communities. The built environment can be defined very comprehensively to include such things as urban land uses, buildings, utilities infrastructure, transportation facilities, parks and various other human-made features. The *Framework* recognizes that the built environment constrains the level of watershed health that it is practical to achieve and sustain. It is not realistic, for example, to expect urban-area watersheds to provide the same level of ecological function as a pristine, undisturbed watershed. Nevertheless, Portland's watersheds provide important habitats for fish and wildlife species and are capable of maintaining ecological functions and processes such as providing clean water.

The key elements of the built environment that most directly affect watershed and river health are physical habitat modification and loss; facilities and management of stormwater, sanitary wastewater, water supply and delivery; and transportation (streets, bridges and so on). Natural processes that take place in the urban setting are modified by features of the built environment. Although these natural features and processes can be negatively affected by the built environment, in many cases the built environment can be modified or managed to minimize its impacts, or even to help improve the natural environment.

Thus, the natural and built environments are linked, and each is influenced by the other. This means that watershed plans and management actions must take into account, for example, how stormwater is currently managed, how roads and other urban features are built and maintained, and how this affects hydrology, physical habitat, water quality and biological communities. Conversely, recommendations to achieve watershed health goals and objectives very likely will include changes to how features of the built environment are constructed, reconstructed and managed. For example, features of the built environment that affect the volume and flow of stormwater, such as roads and buildings, can be designed to be relatively narrow and have small footprints, thus reducing the amount of impervious

[7] See Appendix B for information about these laws.

surface area and volume of stormwater runoff. Measures such as stormwater swales and the disconnection of downspouts can contribute to the storage of runoff and its slow release later, via infiltration.

By applying the processes described in this *Framework*, the City seeks to:

- Understand the built environment and how it affects natural features and processes
- Develop solutions to watershed problems that reflect this understanding
- Modify the way the built environment is developed, redeveloped and managed, to improve watershed conditions

Portland's Watershed Health Goals

It is not realistic or feasible to re-create the environmental conditions that existed before Portland's development. Yet this is not a reason to avoid attempting—through natural, technological or institutional means—to reestablish the ecological conditions and functions needed to achieve and maintain healthy watersheds.

Although the City of Portland does not seek to re-create predevelopment conditions, it is attempting—through natural, technological or institutional means—to reestablish the functions and conditions needed to achieve and maintain healthy watersheds.

The definition of watershed health presented above points to the importance of ecological conditions and functions, particularly conditions and functions related to hydrology, habitat, water quality and biological communities. These four areas represent the primary domains of the natural environment on which the City's watershed management process is based, and for which the *Framework* establishes four citywide watershed health goals[8]:

- Hydrology: Move toward normative[9] flow conditions to protect and improve watershed and stream health, channel functions, and public health and safety.
- Physical Habitat: Protect, enhance and restore aquatic and terrestrial habitat conditions to support key ecological functions and improved productivity, diversity, capacity and distribution of native fish and wildlife populations and biological communities.
- Water Quality: Protect and improve surface water and groundwater quality to protect public health and support native fish and wildlife populations and biological communities.
- Biological Communities: Protect, enhance, manage and restore native aquatic and terrestrial species and biological communities to improve and maintain biodiversity in Portland's watersheds.

[8] The rationale for these goals and the reasons they are presented in this particular order are discussed in more detail under Restoration Guideline 3.4, in Chapter 2, "Scientific Foundation."

[9] A normative flow regime provides characteristics of flow magnitude, frequency, duration and timing essential to support diverse and productive salmonids and all native aquatic species and other flow-dependent resources.

The four watershed health goals are ordered along a continuum of influence, with hydrology playing a major role in shaping elements of physical habitat, such as the amount of large wood in a waterway, the type of substrate (coarse gravel or fine sediment) and the amount of native vegetation in floodplains. Physical habitat, in turn, affects stream temperature and other aspects of water quality. And water quality and physical habitat together help determine which species are present within a watershed and the abundance, productivity and diversity of those species.

Measuring Success

What ultimately counts is actual change in environmental conditions. Thus, success will be defined as achieving objectives, benchmarks and targets, not simply implementing a set of actions.

Objectives. The *Framework* process involves setting watershed-specific objectives consisting of measurable desired outcomes that the City intends to achieve to reach each of the four watershed health goals presented in this chapter. Objectives will be developed following completion of detailed characterizations of current and historical conditions in each of the City's watersheds. The objectives will be tailored to the specific conditions in each watershed and will take into consideration the unique physical conditions, limitations and constraints within each watershed as documented by the characterizations.

Indicators and Benchmarks. Being able to measure and demonstrate progress in achieving objectives and goals over time will be vital. Therefore, a set of environmental indicators and target values or desired conditions for each objective will be established. Benchmarks for achieving the target values or desired conditions will guide the prioritization and timing of protection or restoration actions.

What is adaptive management?

- It is a dynamic process of improving management activities incrementally, as decision makers learn from experience and better information and analytical tools become available.
- It entails clearly defining goals and objectives.
- It involves measuring progress made in achieving watershed goals and objectives, adjusting the management decisions accordingly, rechecking and readjusting—all the while incorporating new data and scientific knowledge.
- It sometimes requires modification of objectives in recognition of the fact that the future cannot be predicted perfectly.

Success will be defined as achieving objectives, benchmarks and targets, not simply implementing actions. The outcome of actions—that is, actual change in environmental conditions—is what ultimately counts.

There is one important caveat to this understanding of success. As the City implements its watershed management process, it is inevitable that new information about watershed ecology and management will emerge. Therefore, the objectives, indicators, target values and benchmarks will be revised as needed to reflect this new information and improved understanding.

The processes described in this *Framework* are not onetime undertakings. Rather, they are iterative and ongoing, and the City of Portland will use them over the coming decades to assess and manage watersheds. The processes described in this document incorporate adaptive management, which provides a means of implementing protection and restoration actions while at the same time testing, revising and retesting hypotheses about how the scientific principles can best be applied. The result will be that new data and improved scientific understanding of watershed ecology and management will continually be applied to a wide range of decision making—from broad policy-level decisions to ongoing, on-the-ground actions.

Salmon as Key Indicators of Watershed Health

As expressed in the watershed health goals, aquatic *and* terrestrial species are important to the City. If biological communities are healthy, it can be assumed that watershed functions and conditions are healthy. Similarly, if salmonid populations are healthy, it can generally be assumed that watershed conditions and functions are healthy. In that sense, salmon are akin to canaries in coal mines.

The health of salmon is an important focus of the *Framework* because the health, abundance and productivity of salmon reflect many key watershed processes. This is not to say, however, that there are not other important indicators of watershed health.

Because the health, abundance and productivity of salmonids are a good reflection of many key watershed processes, this *Framework* pays special attention to the health of riverine/riparian ecosystems, in particular to the health of salmonids and their habitats. Salmon are highly sensitive to all components of watershed health (hydrology, habitat, water quality and biological communities). They are considered a keystone species, meaning that their presence (or absence) is central to many other physical, chemical and biological processes in an ecosystem. They have cultural, economic and regulatory importance. Finally, more is known about the life histories of salmonids and the relationships between stream conditions and salmonids' population abundance and productivity than is known about most other species in the Pacific Northwest.

This is not to say, however, that there are not other important indicators of watershed health. Indeed, this *Framework* presents a number of other potential indicators (see Appendix G), and additional indicators will be identified in the future. As more research on other species of concern is done, the City will update its indicators of watershed health. Similarly, the City will actively monitor information about other species to ensure that the latest information is incorporated into management decisions. It is expected that improvements in hydrology, water quality and aquatic and riparian habitat made to benefit salmonids also will aid some terrestrial wildlife species and help protect and improve their habitats. However, the City of Portland recognizes the need for specific consideration and comprehensive analysis of terrestrial wildlife habitats in order to reach its watershed health goals, particularly its goals for physical habitat and biological communities. The scientific foundation of the *Framework* (see Chapter 2) presents ecological principles that apply to terrestrial components of the ecosystem. In the future, additional analytical tools that more explicitly address terrestrial wildlife habitats will be developed and objectives, indicators, benchmarks, protection and restoration priorities and necessary implementation actions will be identified.

How Is This Watershed Approach Different?

The City of Portland has undertaken many projects and actions that are already improving the condition of its rivers and watersheds (see Appendix C). The approach to watershed management described in the *Framework* builds upon those efforts but differs in several key aspects:

Unlike past efforts, which have focused on water quality, this approach applies principles that recognize how hydrology shapes physical habitat and water quality, and how habitat and water quality, in turn, influence the location and health of biological communities.

- Unlike past efforts, which have focused on water quality, this approach applies principles that recognize how hydrology shapes physical habitat and water quality, and how habitat and water quality, in turn, influence the location and health of biological communities. This scientifically based approach has been reviewed and validated by a team of independent scientists.[10]
- It has clear goals. It calls for establishing sound and measurable objectives, targets and benchmarks and implementing the actions needed to achieve them. It calls for monitoring the result of actions so the City can measure progress toward its goals.
- It is watershed-based, meaning that it provides a way to view everything the City does from a watershed perspective and at multiple watershed scales, from the level of the entire Columbia Basin down to individual subwatersheds.
- It is comprehensive and coordinated, meaning that the City will consider multiple components of physical and biological systems simultaneously, rather than individually.
- It focuses first and foremost on restoring and maintaining healthy watershed conditions, rather than on complying with individual regulatory requirements, one at a time. Improving overall watershed health will improve the effectiveness and efficiency of the City's compliance efforts.
- It integrates efforts across bureaus and programs to create a shared, effective watershed management process, and it stresses the importance of partnering with multiple jurisdictions and stakeholders in the region. The City acknowledges that its actions affect watershed conditions across the Columbia Basin and that the City cannot achieve its watershed health goals acting alone.
- It is ongoing, iterative and applies the principles of adaptive management. It seeks to avoid planting the seeds of future environmental problems.

10 James Lichatowich, salmon biologist and consultant (Chair of the Independent Science Team); Dr. William Liss, Professor of Fisheries, Oregon State University (retired); Dr. Derek Booth, Co-Director of the Center for Water and Watershed Studies, University of Washington; Dr. Kathleen Kavanagh, Assistant Professor of Forestry, University of Idaho; and Dr. Alan Yeakley, Associate Professor of Environmental Science, Portland State University.

Why Take an Integrated Approach to Achieving Healthy Watersheds?

The City of Portland must simultaneously address multiple City watershed health goals and objectives and comply with the requirements of regional regulations and state and federal laws designed to protect human health, water quality, threatened and endangered species and other natural resources. The traditional approach, in which individual bureaus and programs address these topics separately, would result in multiple separate efforts and actions that may be in conflict and that collectively might not achieve the City's watershed health goals and objectives.

The *Framework* process will create opportunities to coordinate work plans, reduce conflicts and duplication of effort, minimize costs and increase the effectiveness of watershed restoration actions.

The *Framework* offers an alternative: an integrated approach that goes beyond merely sharing information and avoiding conflicts. This approach involves working toward a single set of watershed health goals and values; coordinating work plans and timelines across City bureaus; using commonly agreed-upon information and methods; and prioritizing actions to maximize success. The *Framework* approach provides a common "lens" through which many City activities can be viewed and their impacts on watershed health understood. The result will be actions that complement one another, are designed to move toward healthy watersheds and are mutually important to all programs. Additionally, an integrated approach increases the likelihood that City actions will result in net improvements in watershed health over time, while also meeting various regulations and other City goals. And integration fosters the coordination of budgets, grant requests and projects that accomplish multiple City goals in the most timely and cost-effective manner.

There are still other reasons for taking an integrated management approach to achieving healthy watersheds:

- Achieving a citywide vision requires citywide efforts; it is increasingly difficult for individual bureaus to achieve their respective goals and objectives acting alone.
- Much of what Portland does—or regulates—affects river and watershed health.
- Integrated management helps Portland monitor progress by focusing efforts on measurable watershed health results, not simply on compliance with the law.[11] Nevertheless, this approach will move Portland more rapidly toward compliance with various laws and standards, and therefore toward approved or "permitted" activities.
- Consistency and efficiency are greater with an integrated approach, with less duplication of effort and fewer conflicts. It is possible to share resources, which leads to cost savings and wiser expenditure of public resources.

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[11] This is consistent with the National Performance Review, which, in its September 7, 1993, report *From Red Tape to Results: Creating a Government That Works Better and Costs Less*, states, "Federal, state, and local government attention should focus on mutually agreed-upon measurable outcomes for public service delivery."

- Integrated management results in a common information base and shared science to inform all decisions.
- An integrated approach assists the City of Portland in cooperating with other jurisdictions in conducting restoration efforts in watersheds that cross jurisdictional boundaries.
- Integrated management will provide opportunities to coordinate public involvement and attract outside funding.

Relationship of the *Framework* to Other City Plans and Activities

Integrated watershed management as described in the *Framework* is the basis for the following:

- **Development and implementation of comprehensive watershed management plans for Portland's watersheds.** Each watershed plan and its associated documents will identify—and lead to the implementation of—a variety of protection, restoration and monitoring actions needed to achieve the goals for healthy watersheds.
- **Provision of guidance to all City activities and programs that could affect watershed health.** Many activities within the City can affect watershed health. Both the *Framework* and the watershed management plans will provide guidance so that negative impacts are minimized or—better yet—so that City activities actually enhance watershed health.

Clearly, the City's efforts to achieve healthy watersheds will need to take economic and social factors into consideration and be integrated with a host of City plans, programs and projects. Characterization information and recommended actions in the watershed management plans will inform and provide direction to many different City plans, programs and policies. For example, information regarding watershed conditions will be used in many other City efforts, such as parks and neighborhood master planning. It may also be the case that existing City plans will need to be amended to further carry out or accommodate projects that emerge from the watershed management plans. This could include amendments to the City's Comprehensive Plan and codes, the City's stormwater management manual, transportation plans or other documents.

Because transportation, capital, urban renewal, land use and other activities affect watershed health, they need to be as compatible as possible with the City's watershed health goals.

It also is likely that the watershed management process will lead to changes in the way the City of Portland conducts various day-to-day activities, such as land use reviews, vegetation management and road operations and maintenance, because all of these activities have the potential to affect watershed health. Therefore, they must be as compatible as possible with the City's watershed health goals, objectives, benchmarks and approved watershed management plans and actions.

To ensure—to the extent possible—that City plans, programs and activities are compatible with the *Framework* and the watershed management plans, the City's natural resources staff will provide technical and permitting guidance on future City projects so that those projects are planned, designed and implemented in ways that are compatible with watershed health goals and objectives. Guidance will take many forms, including technical memoranda, day-to-day technical assistance, training sessions and policy manuals. More information about ensuring the compatibility of City programs with watershed health goals is provided in Chapter 3.

The guidance provided by the *Framework* and watershed management plans will help ensure that future projects are compatible with watershed health goals.

In essence, the *Framework* and the watershed management plans will be the foundation for guiding, reviewing, planning and implementing many actions within the City of Portland.

Portland Within the Region: What We Do Matters

Portland's watershed management activities will be taking place at the local level but within the context of larger, interconnected natural and built systems that extend through much of the Pacific Northwest. Portland is situated at the confluence of two major rivers, the Willamette and the Columbia. The cumulative effects of land use decisions and on-the-ground actions, hydropower and flood control systems, agriculture and other human activities throughout the Willamette and Columbia watersheds are evident in Portland.

The conditions of Portland's watersheds affect the watershed health of other communities throughout the region as well. For example, every salmonid migrating from every Willamette River tributary and from many Columbia River tributaries must pass through the Portland metropolitan area. Portland's watershed conditions affect aquatic ecosystems, including salmonids, all the way from the McKenzie River to the upper Columbia.

Every salmonid migrating from every tributary to the Willamette River and many Columbia River tributaries must pass through the Portland metropolitan area.

Terrestrial species in the Pacific Northwest also rely on Portland's natural systems during all—or key—life stages. For example, four percent of Oregon's known peregrine falcon population nests within the city limits. Additionally, the largest known Vaux's swift roost in the world occurs in Northwest Portland, and Portland sits on important north-south and east-west migratory corridors used by many species of neotropical songbirds whose populations are in decline.

Portland has a very large "ecological footprint," meaning that what Portland does and how its citizens consume resources affect areas far beyond the City's geographic boundaries. For example, homes are built with timber logged from lands far from the City. The food Portland's citizens consume is grown on farms and ranches beyond the City limits or harvested from the ocean. Dams generate much of the energy Portland requires. The hydropower, timber, agriculture, livestock and other industries that support Portland's activities and economy already have undergone wrenching changes caused by the growing understanding of human effects on natural systems. The Superfund listing, ESA listings and Clean Water Act enforcement actions currently affecting Portland are testaments to the fact that the City needs to be part of the solution to what are actually regional problems.

Planning at the regional or "ecological footprint" scale traditionally is left to federal and state agencies. However, for watershed conditions to be improved and maintained, that tradition will need to be augmented by actions of local governments and communities, who play key roles in land use planning, supplying and consuming energy and clean water, building and maintaining infrastructure, treating solid and liquid waste, and so on. For these reasons, Portland will attempt to consider the effects of its actions at the broadest possible scale while keeping in mind its local focus and obligations. In this, the City hopes to set a positive example. It is only when all entities—at the municipal, state and regional levels—are working toward similar goals that success can be achieved. Given this regional context, the City of Portland is active in many local, state and regional planning efforts related to the Willamette and Columbia rivers (see Appendix D). By participating in these efforts, Portland hopes to increase the chances that upstream, downstream and watershed-wide activities outside the City's jurisdiction will foster watershed health in the Portland area, and that Portland does its part to contribute to regionwide restoration and maintenance of watershed health.

CHAPTER 2

Scientific Foundation

This chapter presents the scientific foundation that supports the City of Portland's watershed management process. Specifically, it describes the principles and guidelines that will influence the City's watershed restoration efforts and the assumptions on which those principles and guidelines are based. To achieve healthy watersheds, both aquatic and terrestrial components will need to be addressed. The primary ecological principles in this chapter, many aspects of the riverine, wetland and upland principles, and the restoration guidelines apply to both terrestrial and aquatic species and habitats.

To achieve healthy watersheds, both aquatic and terrestrial components will need to be addressed.

The Importance of a Scientific Foundation

For much of the twentieth century, the City of Portland viewed the Willamette and Columbia rivers, their tributaries, and the natural resources within their watersheds largely as components in the regional economy that contributed to transportation, agriculture, waste disposal and other forms of commerce. For example, throughout the Pacific Northwest, salmon have been viewed as commodities that could be reared in hatcheries. With this conceptual foundation it is not surprising that the response to the continued decline of watershed health and fish and wildlife populations has been to try to "fix" the environment, to engineer new habitats as habitats have been destroyed and even to modify watershed functions so that they help meet economic needs. In many cases, attempts at environmental and natural resource restoration have not been based on sound information and an accurate understanding of watershed and ecosystem functions and the impacts of human activities on those functions.

Although many improvements have been made over the years, many fish and wildlife populations continue to decline, suggesting that a new approach to managing natural resources is needed. Indeed, current scientific evidence suggests that species and their habitats form a complex, integrated ecological system, and that when this system functions successfully the result is both a healthy environment overall and adequate abundance, productivity and diversity of individual species, including those that are of particular economic or cultural interest to humans.

The scientific foundation that will guide the City of Portland's watershed and fish and wildlife restoration efforts is in alignment with this view of species and habitats existing in an integrated ecological system. As defined by the Independent Scientific Group (2000)[1], a scientific foundation is "a set of scientific principles and assumptions that can give direction to management activities." It attempts to summarize the City's understanding of how the

[1] This was a group of independent scientists that developed a conceptual foundation, review and synthesis of science underlying the Columbia River Basin Fish and Wildlife Program of the Northwest Power and Conservation Council.

ecosystem works and how this understanding can be applied to achieve watershed health goals. A scientific foundation provides a consistent and clearly defined approach to protection and restoration, and it states the assumptions and hypotheses underlying that approach so that they can be scientifically tested and refined over time.

A central tenet of the City's scientific foundation is that reestablishing healthy watersheds will require restoration of ecological functions and conditions. The scientific foundation recognizes that the Columbia and Willamette rivers and their tributaries provide many of the ecological services that are of intrinsic and economic value to humans, such as high-quality water, healthy fish and wildlife populations, safe access to waterways, and recreational opportunities, and that these services also depend on the restoration and maintenance of the ecological system.

Local rivers and streams provide us with valuable services, such as high-quality water, healthy fish and wildlife populations and recreational opportunities. These services depend on the restoration and maintenance of the ecological system.

Scientific information is rarely static, especially in regard to complex ecological systems. Knowledge is gained continually, and new conclusions and directions emerge. For this reason and others, this scientific foundation will be refined over time, through deliberative scientific review. Such review by independent scientists should occur at least every four years, and the scientific foundation should be updated if the scientific review indicates the need for a significant shift in direction.

Scientific Uncertainty and Adaptive Management

The principles presented in this chapter are supported by varying levels of scientific evidence. In some cases, they are supported by an extensive body of peer-reviewed research and apply directly to urban watershed restoration activities. In other cases, the principles represent hypotheses or assumptions that are scientifically plausible and consistent with established scientific principles but that have not been directly addressed by research. While the City's scientific foundation is based as much as possible on previously established principles, many decisions about restoring watershed health will need to be made when there is not enough directly relevant research to guide these decisions unambiguously. A fundamental premise of adaptive management is that encountering such decision points is common. The appropriate response to scientific uncertainty is not to avoid or postpone important decisions but rather to clearly document the assumptions that underlie the decisions and to evaluate the validity of those assumptions by carefully monitoring their results.

As each principle that guides the City of Portland's watershed and habitat conservation efforts is discussed, the level of scientific support underlying that principle is documented and the published sources that support it are cited. This is intended to clearly indicate where each principle lies on the spectrum of plausible hypothesis to well-established scientific principle.

Components of the Scientific Foundation

The principles and guidelines that make up the City of Portland's scientific foundation for achieving watershed health fall into four categories: primary ecological principles; riverine, wetland and upland ecology principles; salmonid ecology principles; and restoration guidelines (see Table 2-1). Many of these—including the primary ecological principles, the restoration guidelines, and aspects of the riverine, wetland and upland ecology principles—apply to the nonaquatic (terrestrial) components of the ecosystem.

TABLE 2-1
Principles and Guidelines Underlying the City of Portland's Scientific Foundation

Category	Principle or Guideline
Primary ecological principles	1. Ecosystems are dynamic, resilient and develop over time. 2. Ecological systems operate on various spatial and time scales that can be viewed hierarchically. 3. Habitats develop and are maintained by processes related to biotic and abiotic components of the ecosystem. 4. The abundance, productivity and diversity of organisms are integrally linked to the characteristics of their ecosystems. 5. Species play key roles in developing and maintaining ecological conditions. 6. Ecosystem function, habitat structure and biological performance are affected by human actions. 7. Biological diversity allows ecosystems to accommodate environmental variation.
Riverine, wetland and upland ecology principles	1. Rivers are not separate from the wetland and upland areas they drain. 2. Watersheds are defined by and operate across the spatial and temporal dimensions of riverine, wetland and upland ecosystems. 3. Hydrologic modification (outside normative flow regimes) and changes in upland conditions, functions and land uses can reduce habitat diversity, decrease native biodiversity, increase nonnative species and exacerbate water pollution, landslides and flooding.
Salmonid ecology principles	1. Life history diversity, genetic diversity and metapopulation organization are ways salmonids adapt to their complex and connected habitats and are the basis of salmonid productivity and salmonids' ability to cope with environmental variation. 2. Sustained salmonid productivity requires a network of complex, diverse and interconnected habitats that are created, altered and maintained by natural physical processes in freshwater, estuarine and ocean environments. 3. Restoration of salmonids must address the entire natural and human ecosystem, encompassing the continuum of freshwater, estuarine and ocean habitats where salmonids complete their life histories.
Restoration guidelines	1. View the whole picture: Watershed restoration efforts need to be placed within the context of the entire watershed; species recovery efforts must be placed within the context of complete life cycles. – 1.1 Define watershed health holistically, by addressing the entire system. Evaluate watershed health in four dimensions: longitudinal, lateral, vertical and temporal. Define watershed health in terms of physical, chemical and biological integrity. – 1.2 Understand the role of the watershed in the landscape. 2. Characterize existing conditions and use the results to inform the entire restoration planning process.

TABLE 2-1
Principles and Guidelines Underlying the City of Portland's Scientific Foundation

Category	Principle or Guideline
	3. When planning watershed restoration actions, prioritize and sequence them to maximize long-term success in meeting the stated objectives for the restoration. – 3.1 Begin recovery efforts by protecting and restoring existing fish and wildlife functions, populations and habitats. – 3.2 Build outward from existing populations, functions, and rare and high-quality habitats. Consider the pattern and connectivity of habitat patches as habitats and functions are built outward. – 3.3 Place priority on controlling sources of degradation before attempting to address the impacts of those sources. – 3.4 In prioritizing restoration actions, first understand how watershed processes affect watershed health. Focus initial restoration actions on the processes that create and maintain healthy watershed conditions and functions. 4. To the maximum extent practicable, use natural processes to achieve ecological functions and societal goals. – 4.1 Minimize the introduction and spread of nonnative plant and animal species, especially into relatively natural habitat areas. – 4.2 Use native species and emphasize natural habitat features and processes whenever possible in restoration activities.

Primary Ecological Principles

The overarching ecological principles are a set of broad, scientifically based statements that describe how the biological and physical features of Portland's watersheds and watercourses form a functional ecosystem and, in turn, how this ecosystem affects the biological performance of species of interest for commercial, cultural or other reasons. These principles are based on a number of principles within the field of ecosystem management, including those of the Northwest Power and Conservation Council's Independent Scientific Group (2000), ecological principles for land management developed by the Ecological Society of America (Dale and others 2000) and those of Quigley and others (1996) for federal land management.

All of the primary ecological principles apply to both aquatic and terrestrial species.

Seven primary ecological principles underlie the City's *Framework*. Principles 1 and 2 deal with the characteristics of ecosystems, Principle 3 deals with habitat-forming processes, and Principles 4, 5, 6 and 7 deal with species' ecological functions and diversity within ecosystems.

The principles are not independent and, in fact, overlap in important areas as a result of the integral coupling of ecosystem components, characteristics and performance. All of the primary ecological principles apply to both aquatic and terrestrial species.

Primary Ecological Principles

1. Ecosystems are dynamic, resilient and develop over time.
2. Ecological systems operate on various spatial and time scales that can be viewed hierarchically.
3. Habitats develop and are maintained by processes related to biotic and abiotic components of the ecosystem.
4. The abundance, productivity and diversity of organisms are integrally linked to the characteristics of their ecosystems.
5. Species play key roles in developing and maintaining ecological conditions.
6. Ecosystem function, habitat structure and biological performance are affected by human actions.
7. Biological diversity allows ecosystems to accommodate environmental variation.

Primary Ecological Principle 1: Ecosystems are dynamic, resilient and develop over time.

Although ecosystems have definable structures and characteristics, their behavior is highly dynamic, changing in response to internal and external factors (Dale and others 2000). The system present today is the product of its geological, biological and human legacy. Natural cycles of change structure biological communities and affect species abundance and distribution (Beamish and others 1999). Disturbance and change are normal ecological processes and are essential to the structure and maintenance of habitats (Bisson and others 1997).

Disturbance can be the result of natural processes such as fire, flood or insect outbreaks, or they can result from human activities, such as the creation of impervious surfaces, development of riparian zones, timber harvest or agriculture. Natural disturbance patterns create a mosaic of habitats across the landscape and through time (Reeves and others 1995). At the same time, ecosystems maintain characteristic features and support definable communities of organisms. Habitat-forming processes—which result from the underlying geology, climate and hydrology and species' ecological functions—impart a degree of resilience to the system, allowing it to accommodate change and maintain essential characteristics (Holling 1973). Once a disturbance dissipates, the ecosystem may come to resemble its previous condition, depending on the type and degree of disturbance and the ecosystem's resilience.

An ecosystem's ability to absorb change and retain its original characteristics is limited, particularly in urban ecosystems, where disturbance is essentially continuous. Under these circumstances an ecosystem may not return to predisturbance conditions even if the disturbance ceases.

However, an ecosystem's ability to absorb change and retain its original characteristics is limited (Holling 1973, Reice and others 1990). Human actions and natural events can dramatically alter ecological systems such that the system is not destroyed but instead shifts into a new configuration in which different species are favored and new biological and physical interactions develop. This is particularly true in urban ecosystems, where disturbance is essentially a continuous rather than episodic event and the resilience of the ecosystem is compromised to the extent that it will not return to predisturbance characteristics even when the disturbance is reduced or eliminated.

A natural ecosystem will show describable, if not generally predictable, patterns of change over time (Odum 1969). For example, a forest, like other ecosystems, may appear stable when observed at one point in time, but it changes over longer time frames. Similarly, a lake or stream matures to have a dramatically different ecological character at various points in time (Cummins and others 1984). Natural disturbances can interrupt succession locally, leading to a mosaic of habitats across the landscape (Reeves and others 1995). More widespread and pervasive disturbance, including many human activities, can stop or reset ecological succession patterns and prevent the formation of habitats and processes that may be essential to the continuation and abundance of some species.

Many natural resource management actions are designed to control the environment, reduce variability, and achieve a stable and predictable yield from a highly dynamic system (Holling and Meffe 1996). For example, dams and other structures are designed to dampen seasonal variation in water flow. In many developed areas, including Portland, river and streambanks are stabilized and diked to minimize out-of-channel flooding during high flow events. Fish hatcheries were conceived, in part, to smooth out natural variation in fish populations and to sustain harvest over time (Bottom 1997). Hatchery production and fish passage measures are timed and engineered to provide a predictable fish migration with minimal conflict with human uses of the river. Fires are suppressed, altering forest succession, species composition and the frequency and severity of insect outbreaks (Quigley and others 1996).

Implications. In accordance with Principle 1, natural resource management programs should anticipate and accommodate both natural and human-induced change. This would be a departure from traditional management, which has attempted to freeze the system in a certain constant state and manage it for constant yields by not allowing natural change to occur. Expectations of constant abundance or yield from natural resources are unrealistic and ignore fundamental features of ecological systems. Similarly, efforts to protect only areas that currently possess desirable conditions, without considering the long-term, dynamic nature of ecosystems, will not result in successful, comprehensive natural resource management. Natural patterns of disturbance should be recognized as events that develop and maintain a diversity of habitats. Efforts to stabilize the environment and reduce disturbance will fundamentally alter habitats to the detriment of the abundance, productivity, spatial structure and diversity of species of management interest, such as ESA-listed salmonids.

Attempts to stabilize and control the natural world through hatcheries, dams and fire suppression run counter to the fundamental nature of ecological systems, which is to be constantly changing.

Given the limited resilience of ecosystems in urban areas, it is not realistic to expect a return to predisturbance conditions. Nonetheless, ecological functions can be restored to some degree. These facts have implications in establishing meaningful objectives, targets and benchmarks for achieving watershed health. Also affecting the establishment of objectives, targets and benchmarks is the expected arrival of an estimated 1.1 million new residents in the Portland metropolitan area by the year 2040.[2] An influx of this magnitude will almost certainly test the resilience of the region's ecological systems and processes and, ultimately, challenge the City's ability to achieve healthy watersheds.

The challenge for the City of Portland will be to allow habitat-forming processes to occur in a built-out environment with high human population densities. The *Johnson Creek Restoration Plan* (City of Portland Bureau of Environmental Services 2001) is one example of an approach that has attempted to do this. The plan calls for buying properties along Johnson Creek to provide flood storage in the floodplain, as well as create off-channel habitat for salmonids. This approach came about as a result of a combination of factors, including strong public support, a history of failed flood control attempts and increased regulatory scrutiny by federal and state agencies as a result of the Endangered Species Act.

Flow regulation in the Columbia and Willamette is one of the most pervasive changes that has been made to these rivers. The confluence of the Columbia and Willamette rivers historically was a site rich in ecological and biological diversity. Flooding, large wood accumulations and tidal influences shaped the factors that aquatic life evolved and adapted to. As the magnitude and rate of flooding have been controlled through reservoirs, habitat-forming processes have been severely altered, if not eliminated. Species such as salmonids and beaver that have evolved complex life history strategies based on the patch-dynamic nature of habitat networks created by disturbance have been forced to use suboptimal habitat patches or move through long stretches of inhospitable habitat. Strategies for the lower Willamette watershed will have to contend with traditional reservoir management of flows and the long history of draining and filling of the floodplains and shoring up the banks with rock, concrete and other structures. Since 2000, the City's Willamette Fish Study, a cooperative effort between the City and the Oregon Department of Fish and Wildlife (ODFW), has been investigating juvenile salmonids' use of bank and near-shore treatments to determine current and future habitat restoration opportunities in the lower Willamette River.

To allow for more natural flow variations, a twofold strategy will be necessary. This strategy will involve adding some controlled habitat-forming flow forces to the traditional management regime of the reservoirs and allowing for some controlled habitat-forming processes to occur in the lower Willamette. The latter will require a regional approach with cooperative agreements among the City of Portland, other local jurisdictions, and state and federal agencies that have jurisdictional authority over flows and the instream, bank and floodplain environment.

Primary Ecological Principle 2: Ecological systems operate on various spatial and time scales that can be viewed hierarchically.

Ecosystems, landscapes, communities and populations are usefully described as hierarchies of nested components (Allen and Hoekstra 1992), with levels in the hierarchies distinguished by different spatial and time scales. A higher level addresses larger areas that fluctuate over relatively long time intervals, whereas lower levels encompass smaller areas

[2] The Metro-approved *2040 Regional Growth Plan* plans for a population increase of 1.1 million new residents in the region by 2040. Among other things, the plan identifies lands outside Portland city limits that will be used to accommodate this growth.

and vary at greater frequencies. For example, factors such as climate and geology might be addressed at a regional scale, hydrology and water quality might be addressed at the watershed scale and localized habitat components might be addressed on a local, site-specific scale. Expansive ecological patterns and processes constrain, and in turn reflect, localized patterns and processes (Wiens 1989).

The appropriate hierarchy and scale to use for watershed management depend on the question asked (Levin 1992). There is no single, intrinsically correct scale, only one that usefully addresses the issue in question. Conditions at any given level reflect both the cumulative effect of actions at lower levels and the constraints imposed by higher level factors (Allen and Hoekstra 1992). Therefore, to understand conditions at any particular level, it is necessary to consider the higher level constraints (the context) and the lower level mechanisms, both of which influence conditions (Wiens 1989). This suggests neither a top-down nor a bottom-up management approach but rather an integration of both.

Viewing ecosystems as hierarchies is useful in depicting the underlying structure of ecological components. Regional climates, for example, vary through time on scales ranging from millennial to interannual (Greenland 1998). Disturbance regimes within ecosystems can be described at a variety of spatial and temporal scales (Delcourt and others 1983) that can affect life history patterns and genetic structure (Wissmar and Simenstad 1998). Frissell and others (1986) describe a hierarchical classification system for aquatic habitats based on underlying geomorphic hierarchies.

This principle also provides an ecologically based way to structure watershed recovery (Quigley and others 1996). As a necessary first step, the ecosystem is defined at the point in the ecological continuum appropriate to the problem to be solved. The ecosystem at that point reflects both the characteristics of the features nested within it and higher level constraints on performance.

Implications. If ecosystems are viewed as nested hierarchies, it is necessary to define appropriate scales for their management and study (Holling and Meffe 1996). To address problems in the entire Willamette River basin, for example, it may be necessary to filter out local, site-specific data. On the other hand, questions concerning localized components (such as the Willamette's reach within Portland or tributaries to the Willamette, such as Johnson and Tryon creeks) cannot be effectively addressed by looking solely at the entire basin. Understanding basin-level problems requires knowledge of actions and processes that take place in individual reaches and tributaries, while the success of reach- or tributary-level actions may depend on factors operating at basin and regional levels.

Effective restoration of physical, chemical and biological components of the lower Willamette River and tributary streams will require coordination with upstream jurisdictions as well as with agencies that control water flows, water quality and fish and wildlife communities. This will involve working at multiple scales involving both the site-specific and the basinwide context. There will need to be an agreed-upon series of indicators for use in determining current conditions, measuring the progress of restorations actions and monitoring on-the-ground changes to a variety of ongoing operations and maintenance activities. Such a set of indicators is being developed as described in Appendix G, and they will need to be accepted by key stakeholders in the region.

In addition, empirical studies and monitoring will need to be designed and funded to track the progress of restoration actions. The challenge will be in deciding on the priorities for data collection and maintaining a coordinated data system across so many different scales and jurisdictions. The Willamette Partnership (formerly the Willamette Restoration Initiative, or WRI; see Appendix D) may offer the best example yet of how this could occur.

Primary Ecological Principle 3: Habitats develop and are maintained by processes related to biotic and abiotic components of the ecosystem.

Habitat refers to the resources and conditions present in an area that allow a species or a group of species to exist and thrive (Hall and others 1997). From a species perspective, the habitat is the string of conditions encountered over the species' life cycle that contribute to the species' survival and reproduction (Independent Scientific Group 2000). Factors such as geology, climate, geomorphology, soils, hydrology, vegetation and topography regulate habitat-forming processes, which for salmonids include stream flow, contributions of large wood, sediment supply, temperature and channel dynamics (Frissell and others 1986, Imhof and others 1996, Beechie and Bolton 1999). All of these elements act over a range of spatial and time scales to create, alter and maintain habitats (Allen and Hoekstra 1992).

Habitats exist in specific localities, but they are created by processes and factors that extend throughout watersheds, basins and even regions.

Regional-scale climatic conditions determine temperatures and precipitation that are important in the development of habitats. At both the regional and local scales, habitats are created and maintained by hydrologic, geologic and biotic processes that affect other aquatic and terrestrial conditions throughout the watershed. Locally observed conditions often reflect more than local processes and influences; in fact, they often reflect non-local—even regional—processes, including human actions. The presence of essential habitat features created by these processes determines the abundance, productivity, spatial structure and diversity of species and communities (Morrison and others 1998).

The active agent of many aquatic habitat-forming processes is water acting with the underlying geology and topography. Because habitat processes are hydrologically linked, the impacts of actions can manifest themselves downstream. As an example, downstream habitat conditions (such as high water temperature or increased sediment) can be the result of upstream actions and conditions (such as the removal of trees along streambanks or streamside construction). The impacts of these terrestrial actions and conditions accumulate (that is, the water temperature increases continually) as water moves downhill, affecting aquatic habitat conditions downstream.

Terrestrial habitats are often described in terms of food, water and cover. Formation of these features is related to vegetative and biotic patterns that result from the environmental needs of individual plant species, succession and patterns of human-caused and natural disturbance (Whittaker 1975). In turn, the vegetation pattern is related to local geology, topography and climate in the context of the regional climate and other factors. In an urban context, terrestrial habitats are often described in terms of their land uses, levels of impervious surface and vegetative cover.

Implications. Understanding the processes that create and maintain aquatic and terrestrial habitats is key to managing the human impacts on those habitats (Imhof and others 1996, Beechie and Bolton 1999). Even though the perceived problem may be local, it is necessary to consider the habitat-forming processes acting at the watershed or basin level. Often efforts are focused on correcting the symptoms of habitat degradation and loss, rather than on their causes, and problems are addressed with local, technological solutions. Often these efforts prove futile because the process and conditions creating the problem are still in place (Kauffman and others 1997).

Habitats are the result of processes. Restoration efforts are most likely to be successful if they are based on an understanding of the processes that form a particular habitat.

This principle stresses the need to understand and address habitat-forming processes in order to restore and maintain aquatic and terrestrial habitats (Beechie and Bolton 1999). Habitat restoration actions undertaken without appreciation of the underlying habitat-forming processes will not be effective in the long term (Reeves and others 1995).

Land use affects habitats through processes similar to those structuring natural habitats. Understanding the relationship between land use practices and their impacts on ecological processes and functions is key to ensuring that habitats are available to support biological communities and species of interest. For example, one risk to terrestrial species is habitat fragmentation as a result of development. Small patches of fragmented habitat are less likely than large habitat patches or habitat corridors to sustain ecological processes and disturbance regimes that support viable and diverse populations of native plants and animals. As the human population increases in the urban area, the City of Portland will need to identify those habitat patches where habitat-forming processes are still relatively intact so that populations of key terrestrial species, such as western gray squirrel and red tree vole, can be maintained.

In urban areas such as Portland, efforts have been made over the life of the City to control or eliminate the impacts of flooding, with the result that important habitat-forming processes that native aquatic species have adapted to have been altered. Controlling water flows through reservoirs and dams has given many people the sense that rivers can effectively be separated from their floodplains. Activities such as filling floodplains and building flood control bank structures have given human populations the perception that they can safely build next to streams and rivers.

As the population continues to increase in the Willamette River basin, the size and impact of cities located along the river corridor will increase. This will present the challenge of how to allow habitat-forming processes to occur via careful management of high flows, in conjunction with restored bank and floodplain habitat. It also will be necessary to change the management of reservoirs and dams and redesigning fish-friendly bank and near-shore treatments to handle the increased flows while also providing ecological benefits. Given the potential for conflict with regard to historical uses and properties, there will need to be an educational component in addition to coordination to facilitate decisions at site- and basinwide scales.

Primary Ecological Principle 4: The abundance, productivity and diversity of organisms are integrally linked to the characteristics of their ecosystems.

An ecosystem is an organized complex of physical and biological components (Tansley 1935). Physical and biological elements such as minerals, soil, vegetation and animals self-organize into a system that captures and processes energy to produce the observed diversity, abundance and productivity of plant and animal species, including humans (Kauffman 1993, Odum 1993). The characteristics and abundance of individual species reflect their coevolution with other species and their response to their environment. Because of the pervasive impact of human actions on ecological systems (Vitousek and others 1997), achieving goals for individual species of commercial, cultural or other human interest will require managing human activities to support ecological processes (Christensen and others 1996).

Although scientists may have an intuitive feel for what constitutes an ecosystem, management goals and actions frequently focus on individual species rather than on the species' ecosystems—the physical and biological systems that species are a part of, contribute to and depend on. In the past, species of commercial and cultural concern have been given priority, with sporadic success. There is increasing recognition of the need for multiple species management and the integration of land management with fish and wildlife management (Puchy and Marshall 1993, Christensen and others 1996, Dale and others 2000). This means recognizing both the processes that form the habitats necessary for species (processes such as channel dynamics and habitat connectivity) and the functions that species provide to the ecosystem (such as input of organic matter, primary and secondary production and energy flow). For example, many of the flood control dams constructed in the upper Willamette River basin did not provide fish passage, thereby eliminating crucial nutrient cycling. The combination of suitable habitats and needed ecological functions combine to form the ecosystems needed to provide the desired abundance and productivity of specific species.

Local climate, hydrology and geomorphologic factors as well as species interactions strongly affect ecological processes and the abundance and distribution of species at any one place (Dale and others 2000). The life histories, physical features and diversity of individual species are shaped by climate, the physical structure of their habitat and biological interactions. Change in physical or biological features of the ecosystem, either natural or human-induced, affects the capacity, productivity and diversity of fish and wildlife species.

Implications. Management of species or ecological problems in isolation at best provides an incomplete picture and at worst misleads by not accounting for the context and mechanisms that control species abundance, capacity and diversity, or the ecological processes that support these. This principle notes the integral relationship between species and their environment and the role that species themselves play in maintaining that environment. It couples ecological conditions with the productivity and abundance of species, including those of management interest.

Natural resource management, especially fisheries management, often isolates species from their environment to insulate them from habitat loss or other impacts of human actions (Bottom 1997). Insulating species in this manner neglects the role of biological and physical factors of the ecosystem—such as dynamic conditions of flow, habitat and water quality—in shaping individuals, populations and species through natural selection. In addition, this approach does not replace habitats themselves or the ecological functions that species provide, such as supplying nutrients and food to other species. For salmon, hatcheries historically have not been successful. This is not to say that hatcheries do not have a role to play in salmonid recovery, particularly during the stages in which habitat and ecological functions are being restored. Rather, hatchery operations should be conducted with an understanding of the contribution salmonids make to healthy functioning of the ecosystem and the reliance of salmonids on biological and physical characteristics of their environment.

It will be crucial to understand which habitat and ecological functions or processes in the lower Willamette and its tributaries play key roles in providing rearing, feeding, and spawning habitat, and in providing for other needs of native biological communities. The Willamette Fish Study, a fisheries research effort of the lower Willamette River by the City and ODFW, is attempting to do this for juvenile salmonids, but this type of investigation must be extended to other species as well, both aquatic and terrestrial (bald eagles and turtles, for example).

Primary Ecological Principle 5: Species play key roles in developing and maintaining ecological conditions.

Organisms do not act as passive occupants of their habitats. Instead, each species has an ecological function that may be key to the development and maintenance of ecological conditions such as habitat and food supply (Walker 1995). Although not every species' ecological role is well understood, it is clear that each group of species has a distinct job or "occupation" that is essential to the diversity, sustainability and productivity of the ecosystem over time (Morrison and others 1998). For example, plant, animal and bacterial species structure habitats, cycle energy and control species abundance and diversity. Beavers create ponds, plants make the sun's energy available to herbivores (and ultimately carnivores) and bats help keep mosquitoes in check. The existence, productivity and abundance of species depend on functions such as these.

To varying degrees, similar ecological functions may be performed by different species, and having a diversity of species with similar "occupations" enhances the resilience of the entire ecosystem in the face of disturbance or environmental variation (Walker 1995). However, some ecological functions are performed by a limited number of species. The decline or disappearance of these species can have significant impacts on their associated ecological function, the ecosystem as a whole and other species.

A species does not just live in and rely on its ecosystem; it also performs functions that contribute to the healthy functioning of that system, such as shaping habitats, funneling energy from the sun to other organisms and keeping the populations of other species in check.

In Pacific Northwest ecosystems, for example, salmon often play a unique role in cycling nutrients and energy from the ocean to freshwater and terrestrial habitats (Cederholm and others 1999). Salmon carcasses naturally fertilize freshwater systems, providing a unique array of nutrients, lipids and biochemicals to freshwater and riparian food webs. Algae, bacteria, invertebrates and young salmon fry in particular depend on these nutrients—many of them marine-derived—to survive and remain viable throughout the year. In fact, "the watershed fertility once provided by healthy runs of salmon may be essential to recovery of declining salmon stocks" (Pacific Northwest Research Station 2001). The disappearance or decline of salmon stocks in a particular watershed can have far-reaching impacts on coexisting aquatic and terrestrial plants and wildlife; these impacts include changing the nutrient cycle and other ecological functions (Willson and Halupka 1995, Cederholm and others 1999).

Salmon hatcheries may provide harvest benefits to some human users when habitats have been altered or destroyed, but generally hatcheries do not replace the ecological role that salmon play in the ecosystem, such as nutrient cycling. Recent experiments show that placing hatchery-origin salmon carcasses into streams (one carcass per square meter) jump-starts trophic level production and results in accelerated growth rates in fish. Through its Salmon Trout Enhancement Project, ODFW enlists volunteers to place carcasses in streams. Although the ecological impact of these particular carcass placements has not been measured, the strategy of carcass placement remains a potential short-term method for incorporating marine-derived fatty acids and biochemicals into aquatic food webs. (It should be noted, however, that just as some streams have never supported certain fish populations, individual watersheds will respond differently to added nutrient loads, depending on biological, chemical and physical attributes unique to that system. Also, in urban areas it may be necessary to investigate the use of other fertilization techniques to avoid nuisance impacts to local human residents.)

Implications. This principle affirms the need to consider resource management actions in the context of species' ecological functions. In the case of salmon, it is generally understood that spawned-out carcasses provide important nutrients to ecosystems as the carcasses decompose and release minerals. Although scientists do not know the degree to which declines in local salmon runs—and the concomitant changes in nutrient cycling—have affected Portland's watershed ecosystems, the declines have doubtless had an effect. The result can be significant ecological change affecting the presence and abundance of other aquatic and terrestrial species (Cederholm and others 2000).

If a species disappears from an ecosystem, so too does its contribution to the healthy functioning of that ecosystem.

Ill-placed or poorly designed culverts or other fish passage barriers affect the number of salmonids that can return to spawn, the temporal and spatial distribution of salmonids throughout a subbasin and—ultimately—the nutrient balance of that freshwater system. In Portland, there are only two waterways that are "open": Johnson Creek and Tryon Creek. The remaining freshwater systems in Portland either are available to salmonids only seasonally or are totally unavailable. Managing Portland's waterways so that salmonids can return unimpeded to spawn will be critical to reestablishing the nutrient bank in those freshwater systems.

Hatcheries may continue to play a role in natural resource management, but their operation must be changed so that they not only bolster salmon survival but so they restore or replace the functions that salmon provide in the ecosystem and boost the overall carrying capacity and productivity of the environment.

Primary Ecological Principle 6: Ecosystem function, habitat structure and biological performance are affected by human actions.

Humans play an integral role in ecosystems and are subject to the same ecological principles as other organisms are. However, we are unique in that we have the ability to shape our ecological future.

Humans are integral parts of ecosystems, and human actions have a pervasive impact on the structure and function of ecosystems; at the same time, human health and well-being are tied to the condition of the ecosystem (Vitousek and others 1997). Like many other organisms, people structure and control ecosystems for their own needs. In some ecosystems, particularly urban ones, human impacts are major factors controlling the environment. However, unlike other organisms, humans can consciously control their actions to allow needed ecological conditions to develop. While human actions may be unique in the scale of their impact on ecological systems, the method of interaction is not; ecological principles apply to human interactions with ecosystems as much as they do to the interactions of fish and wildlife species with the ecosystem.

It is a reasonable assumption that for most species, the ecological conditions that are most conducive to their long-term survival and productivity are those under which they evolved. But urbanization and associated human actions in the Portland area—as in other similar urban areas—have shifted ecosystems away from their predevelopment conditions, with negative impacts for many native plant and animal species. Some changes are irreversible: the urbanized landscape has been permanently changed; increased stormwater runoff has altered flow, water quality and habitat conditions in stream channels; and nonnative plant and animal species have been introduced that compete with and in some cases displace native species. Even with complete cessation of urban development, the ecosystem would not return to its previous condition. However, the impacts of urbanization and associated human actions on ecosystems can be managed to move the system to a state that is more compatible with the needs of other species.

Implications. Some people view humans as separate and distinct from the natural world—as observers and users rather than as active participants. Principle 6 stresses the integral role of humans in the ecosystem and their unique ability to shape society's ecological future. For millennia, humans have altered the natural landscape in the Willamette River basin and the abundance and distribution of its plants and animals. In intensely developed areas, human activities will continue to dominate the ecosystem. However, it is possible to manage those actions in a manner that is more consistent with the needs of other species and ecological processes.

Human impacts on the ecosystem can be managed to make the system more compatible with the needs of other species.

As scientists learn more about urban ecosystems, there will be more opportunities to incorporate considerations related to ecological functions and processes into traditional urban development and redevelopment objectives. Ecosystem objectives do not have to be incompatible with urban objectives. For example, fish and wildlife-friendly objectives can be incorporated into streambank, near-shore and upland developments and redevelopments along with more traditional objectives, such as flood control. Zoning can establish and protect effective riparian corridors along streams and rivers and upland vegetation to buffer the impacts of humans on the aquatic and terrestrial systems. Stormwater best management practices can be implemented to detain and infiltrate stormwater onsite at existing facilities and redevelopment sites, thus reducing high stormwater runoff flows.

As the more deleterious impacts to Portland's urban streams are addressed, it will be important to track the responses of fish, wildlife and plant communities. An effective monitoring system should be designed to determine whether the City's programs and actions are successful.

In addition to the investigation of City-controlled activities and their effects, studies should also evaluate how state programs, such as ODFW's hatchery and unfed fry release programs, are affecting the City's ability to reach its goals. As the City directs resources to assisting in the recovery of listed salmonid species, it should be determined whether hatchery programs have helped or hindered resident fish populations. As the cumulative impacts of urbanized systems are better understood, hatchery programs should be fine-tuned to assist in the recovery of resident native populations.

Primary Ecological Principle 7: Biological diversity allows ecosystems to accommodate environmental variation.

Biological diversity occurs at a variety of scales: in the variety of life forms across the landscape, in the ecological roles they play and in the genetic diversity within their populations (Odum 1993). Biological diversity develops as a result of various physical and biological processes in response to variability in the physical and biological conditions of the environment (Southwood 1977). Variation in biological characteristics among species, populations and individuals is what drives adaptation in response to environmental variation.

Biological diversity contributes to ecological stability and resilience (Walker and others 1999) at two levels:

- **Within ecosystems.** Resilience is enhanced by the presence of multiple, functionally similar species within a single ecosystem. As the populations of individual species increase or decrease over time, they can alternate in providing essential ecological functions (Morrison and others 1998, Peterson and others 1998, Walker and others 1999). Species that are abundant contribute to ecological function and performance at a particular time, whereas rarer species contribute to ecological resilience over time (Walker and others 1999). Loss of species, particularly those for which there are few ecological equivalents, jeopardizes overall ecological structure and stability (Walker 1995).

- **Within a species.** Genetic diversity contributes to the stability of a species over time by providing a wider range of possible evolutionary responses to the challenges posed by variation in the environment. As the environment changes over time, survival rates vary from one population to the next. As some populations suffer under an environmental extreme such as an El Niño condition, others might fare better. However, the species as a whole survives, bolstered by its ability to respond to the shifting environment (Bisbal and McConnaha 1998).

Human actions often reduce biological variation at both levels (Urban and others 1987, Policansky and Magnuson 1998). As the environment is simplified and its natural variability is decreased, biological variation at the various scales is reduced as well. This leads to the potential loss of organisms as they become less capable of responding adaptively to environmental change. The subsequent loss of ecological functions (functions that the organisms formerly provided) can decrease the stability and resilience of ecosystems.

Biological diversity serves as a natural modulator of ecosystems, helping them remain stable and resilient in spite of environmental changes.

Implications. Activities should be managed to encourage natural expression of biological diversity. While diversity can be quantified, it probably is not possible to determine the "proper" level of biological diversity, partly because it varies over time in response to various physical and biological processes. Furthermore, because future environments or situations cannot be predicted, the level of biological diversity needed to maintain future ecological systems cannot be known. It is not simply that more diversity is always good; in fact, increasing diversity by introducing nonnative species can actually disrupt ecological functions. Rather, it is important that the ecosystem be able to express its own species composition and diversity, so that it remains productive and resilient in the face of environmental variation. The challenge is to manage human activities to encourage the development of compatible native biological communities while at the same time minimizing our impacts on selection so that diversity can develop accordingly.

Riverine, Wetland and Upland Ecology Principles

Ecosystems and fish and wildlife species evolved in response to dynamic patterns and processes occurring along three spatial dimensions of the landscape and one temporal dimension. The spatial dimensions are longitudinal (upstream-downstream), vertical (within the groundwater system and above ground, including tree canopies and the atmosphere), and lateral (across streambanks and floodplains to uplands). To understand watersheds as ecosystems, one must understand the ecological processes functioning throughout the entire watershed, in these four dimensions (Stanford and others 1996). This approach can be used to identify the components necessary to maintain a productive riverine, wetland and upland ecosystem and the processes that control the distribution and health of not only salmon but all biota within Portland's watersheds.

Riverine, Wetland and Upland Ecology Principles

1. Rivers are not separate from the wetland and upland areas they drain.
2. Watersheds are defined by and operate across the spatial and temporal dimensions of riverine, wetland and upland ecosystems.
3. Hydrologic modification and changes in upland conditions, functions and land uses can reduce habitat diversity, decrease native biodiversity, increase nonnative species and exacerbate water pollution, landslides and flooding.

Riverine, Wetland and Upland Ecology Principle 1: Rivers are not separate from the wetland and upland areas they drain.

Riverine Areas. Rivers are not separate from the lands they drain (Hynes 1975). In developing river protection and restoration strategies, it is essential to understand the linkages among terrestrial and aquatic components and processes within watersheds (Stanford and others 1996).

Contemporary river ecology theory is guided by a number of intertwined concepts derived from empirical studies that demonstrate these linkages and apply to all rivers:

- Rivers are networks of surface and groundwater flow pathways that drain watersheds.
- Flowing water constantly reconfigures the physical form of these interconnected flow pathways, primarily through flooding.
- Inorganic and organic materials are eroded upstream and deposited downstream primarily in relation to long- and short-term flow dynamics, the resistivity of geological formations to erosion and dissolution, instream retention structures (such as large wood and boulders) and the geomorphology of the watershed.
- Channel morphologies are determined by the legacy of flooding. Big floods fill channels with inorganic and organic material eroded laterally and vertically at upstream locations, thereby producing (1) a continuum of instream structures, such as pools, runs, riffles, gravel bars, avulsion channels, islands and debris channels, and (2) lateral floodplain terraces in many sizes and shapes.

Wetland Areas. Wetlands can occur in a stream channel, riparian area, floodplain or upland area. All of these wetland environments connect rivers and streams to the lands they drain in a similar manner. They also have similar effects on hydrology and water quality and provide habitats that are crucial to a healthy watershed.

Vegetation and gentle slopes tend to slow water as it passes through a wetland, which forms a transition between aquatic and terrestrial environments. Wetlands perform several important functions within a watershed, and these functions vary with wetland type. During storm events, wetlands slow and temporarily store stormwater, thus reducing peak flood flows and allowing time for infiltration to occur. In this way, wetlands can reduce the risk of downstream flooding and facilitate groundwater recharge. Detention basins, floodplain depressional marshes and wide stream corridors provide important natural flood control.

Wetlands can greatly improve the quality of water passing through them by slowing the flow of water such that sediments have time to settle out. Wetland vegetation and aquatic microbes remove nutrients from the water, reducing the potential for downstream nutrient enrichment. By promoting sedimentation, wetlands also help cleanse water of toxic pollutants because toxic contaminants such as heavy metals and organic compounds often adhere to sediment particles. Riparian vegetation greatly enhances river and stream conditions by providing shade, bank stabilization, stream flow moderation, fine and large woody materials, organic and inorganic debris, terrestrial insects and habitat for riparian-associated wildlife (Hollenbach and Ory 1999, Metro 2002a, City of Portland Bureau of Planning 2001).

Generally, wetland areas provide diverse and productive habitats for many species of fish and other aquatic organisms, amphibians, reptiles, birds, mammals and plants. The vegetation and animals in riparian and floodplain areas, which are a subset of wetlands, are crucial to healthy aquatic environments. For example, functions performed by beaver provide habitat for fish and wildlife. Natural or restored riparian areas provide cavities, woody debris, nesting and roosting areas, food and microclimates for terrestrial wildlife species. By producing vegetation, invertebrates, fish and wildlife, riparian areas contribute significantly to the food web. In the Portland Metro region, 93 percent of all wildlife species regularly use water-associated habitats around streams, wetlands and lakes, and 45 percent are closely associated with these habitats (Metro 2002a). Because the few remaining riparian areas comprise a small portion of the existing landscape, it is important to maximize their conservation for the health of the entire watershed.

Retention or restoration of a sufficient natural riparian buffer with mature, native vegetation has been shown to help sustain functioning aquatic communities in urban areas and can partially ameliorate the adverse effects of urbanization on aquatic wildlife (Horner and others 2002). Large patches of riparian buffer habitat are typically considered more important than smaller ones because large patches tend to include more viable populations of native plants and animals, including species that depend on interior habitat. In addition, large patches are more likely to sustain ecological processes and disturbance regimes. However, small patches also can be important conservation targets because they may contain unique or rare habitat types or species or act as stepping stones between otherwise isolated patches of habitat. Small patches may also provide sufficient habitat for species that do not require large areas, such as frogs and salamanders (Defenders of Wildlife 2003).

Riparian habitats provide corridors for travel and dispersal. These corridors are valuable conservation tools (Beier and Noss 1998), in part because they connect habitats sufficiently to improve the viability of populations in those habitats. Generally, natural landscapes are more connected than landscapes altered by humans, and protection and restoration of corridors can serve as a strategy to enhance or retain some of this natural connectivity. In addition to its connectivity, a riparian area's width and the quality of its habitat affect its value as a wildlife corridor.

Upland Areas. Uplands are those areas that are not riparian, wetland or open-water habitats. Generally, uplands are located uphill of rivers, streams and wetlands and do not have stream channels draining into them; rather, they serve as groundwater recharge areas and also contribute surface water runoff to stream channels.

Natural or relatively undisturbed upland areas provide substrate such as sediments and gravels, nutrients and large woody debris to stream channels via mass wasting on slopes and in ravines and, to a lesser extent, via overland flow (in developed areas with impervious surfaces) and subsurface flow in the soil mantle (in more natural areas). Upland areas also intercept precipitation, slow runoff and filter nutrients and pollutants before they make their way to streams. This is especially important in urban areas, where large portions of the landscape may be impervious (Booth and others 2001). Uplands also provide crucial habitat values for wildlife species at various stages in their life cycle, including breeding, feeding, foraging, dispersal and over-wintering (Hollenbach and Ory 1999). Eighty-nine percent of all terrestrial species in the Portland area, including several bat and owl species, western gray squirrel, and red tree vole, are associated with upland habitats. Additionally, uplands often provide critical migration corridors for a range of terrestrial species, such as western gray squirrel, red and gray fox, and coyote.

Although most upland habitats in the Portland metropolitan area have been altered by human use, considerable amounts of upland habitat resources remain. Important upland resources exist on privately owned lands, but some of the region's upland resources occur on public land. For example, in Portland parks, the following natural vegetation types provide significant wildlife habitat values (City of Portland Parks and Recreation 2005):

- Mixed evergreen-deciduous forest
- Deciduous forest
- Evergreen forest
- Deciduous open woodland
- Mixed evergreen-deciduous open woodland
- Deciduous shrubland
- Perennial grassland vegetation

Forest historically was, currently is, and likely will be, the predominant and largest habitat in Portland parks. In contrast, shrubland is scarce. Although meadows occur in some city parks, they are not natural remnants. Nonetheless, these provide important habitat values.

Implications. Located at the confluence of two sizable rivers—the Columbia and Willamette—Portland was built in large part by separating the wetlands and uplands from the rivers and streams. This was done by controlling floods and baseflow levels. Reservoirs and dams were built, floodplains were drained and filled, "flood-proof" bank treatments such as seawalls were constructed and rainfall was transported as quickly as possible to the nearest waterbodies through an elaborate network of pipes. Upland forests and woodlands were removed to make way for neighborhoods, institutions and commercial enterprises.

In the past, the complexity of issues dealing with flowing waters in an urban area often overwhelmed planners, engineers, biologists and ultimately decision makers. Faced with an array of problems such as flooding, stormwater runoff, water quality health threats, odor, safety issues, recreation demands, increasing domestic water needs and lack of adequate natural environmental amenities, each discipline has responded separately by narrowing and simplifying the problems.

This simplification has had the effect of compartmentalizing the problems in rivers and streams in a way that encouraged isolated, objective approaches such as channelizing streams to move floods through more quickly or combining sewer and stormwater pipe systems to increase efficiency, without a full understanding of the long-term and unintended consequences. Today the cumulative effects of these simplified actions are clearer, and in some cases governments and citizens are paying the consequences (an example in Portland is a court order to reduce combined sewer overflows into the Willamette River by 2011).

It will be important as the City corrects these problems to coordinate current and future actions so that multiple objectives (riverine, wetland and upland) can be addressed. The *Johnson Creek Restoration Plan* (City of Portland Bureau of Environmental Services 2001) is one example of a strategy to manage flooding by reconnecting flood waters with their floodplains for stormwater attenuation. The plan also is intended to achieve additional objectives, such as the creation of off-channel habitat for fish and wildlife.

The *Framework* will be the blueprint for coordinating multibureau and interdisciplinary goals and objectives to meet regulatory, watershed health and community goals and needs. As the City continues to examine ways of restoring rivers, watersheds and salmon other populations of native species, it will need to examine how rivers and streams can be reconnected to the wetlands and uplands they drain in a manner that is acceptable and feasible in an urban context.

Riverine, Wetland and Upland Ecology Principle 2: Watersheds are defined by and operate across the spatial and temporal dimensions of riverine, wetland and upland ecosystems.

As a result of fundamental physical processes, three important spatial dimensions operate within watersheds: longitudinal (upstream-downstream, from headwaters to river to estuary), lateral (from river to streamside to floodplain) and vertical (from the river's water column to groundwater) (see Figure 2-1). Each of these spatial dimensions operates on a temporal (time scale) dimension as well. Consideration of dynamic interactions along all four dimensions will improve understanding of the critical components necessary to maintain a productive river.

- **Longitudinal dimension** (upstream-downstream). This includes the occurrence and ecological significance of streamside (riparian) vegetation and fauna in the surficial transition zone from riverine to upland environments, up and down the river. The distribution of blocks of habitat, or "patches," is an important component in wildlife habitat relationships. The amount of habitat, variation in patch size and isolation of certain patches influence species viability and diversity.

- **Vertical dimension** (complex groundwater, or hyporheic, habitats and above-ground structure). This dimension is created by the penetration of river water through the highly porous bed sediments in gravel-bed rivers. The river water saturates the alluvial bedding of the channel and floodplain down to the less porous bedrock. This dimension encompasses vertical variability in conditions in the water column, such as temperature and dissolved oxygen, and it applies to structure—shrubs, trees and buildings—provided by the biotic and physical environment.

- **Lateral dimension** (floodplain). This dimension encompasses both hyporheic and riparian habitats. It acts as the transition zone linking aquatic and terrestrial components of the river ecosystem above and below ground. Dispersal across the landscape through the lateral dimension is an important function for the viability of most species. Although it may not be necessary to connect all patches, in an urban environment it is important to evaluate which species and life stages could benefit from the connection of both large and small patches.

- Temporal dimension (time). This reflects the dynamic, changing nature of riverine ecological processes over time, such as daily, seasonally, annually or over centuries. For example, there are diurnal (day-night) fluctuations in water temperatures and seasonal changes in flow, runoff and the migration and life stage development of fish and wildlife.

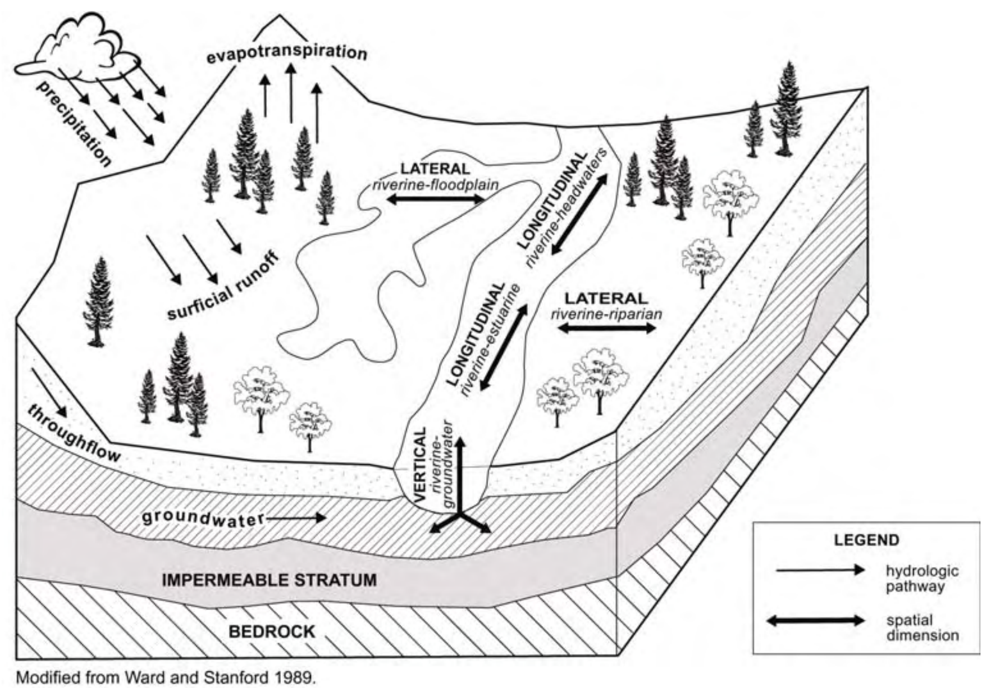

FIGURE 2-1
The Three Spatial Dimensions of Landscapes: Longitudinal, Vertical and Lateral

Rivers that are connected to their floodplains and subject to natural hydrological dynamics, such as flooding, maintain a wider variety of species and food webs than do rivers that rarely or never have scouring floods. Most medium- and low-gradient rivers are naturally flood-prone, such that both the biota and the physical structure of the river ecosystem are controlled by the highly dynamic scouring process of floods. This is consistent with Primary Ecological Principle 1. Floods maintain channel and floodplain habitats and pulse nutrient-enriched waters laterally into backwaters and onto floodplains, as well as downstream into the estuary. Because floods are a continual habitat-forming process, river biota are adapted to the frequency and duration of flood pulses (Junk and others 1989).

Floodplains appear to function as centers of biological and physical structure and organization within the river continuum (Regier and others 1989). Floodplains are likely to be "hotspots" of biodiversity and production that are structurally and functionally linked by the river corridor. The hyporheic and riparian corridor is expansive on alluvial reaches (meaning reaches subject to flooding). Seasonal water temperature patterns vary within the wide array of aquatic habitat that exists laterally from the channel across the floodplain. Food webs are complex and change predictably along the stream continuum in direct response to variations in the strength of interconnections between channel, groundwater, floodplain and upland elements of the watershed.

Urban environments are characterized by built structures, impervious surfaces, reduced forest cover, altered streams and nonnative vegetation. Frequent human disturbance is to be expected in urban habitats, and species that are disturbance-sensitive tend to be absent or reduced in numbers (Marzluff and others 1998). Habitat generalists (northern raccoons and American robins, for example) and nonnative species (such as European starlings and eastern gray squirrels) tend to be most common in urban environments. However, urban environments may also provide habitat to species that require specific and relatively rare micro-habitat features such as cavities, caves, cliffs and rocky outcrops, and ledges (Metro 2002a). For example, peregrine falcons are known to breed on bridges and other artificial structures within the City of Portland, and bridges provide roosting habitat for bats. Portland has several important remnant patches of natural habitat—notably Smith and Bybee lakes, Forest Park and Ross Island—that accommodate a variety of sensitive and common wildlife species.

Most of the riverine, wetland and upland habitat in Portland occurs as patches within a developed urban landscape. Large habitat patches tend to support more biodiversity than small patches, containing more species and individuals than do smaller patches of the same habitat. Typically, large habitat patches consist of interior habitat and an outside ring of edge habitat. These large patches often support both species adapted to edge environments and those adapted to interior habitats. As patch size decreases, the proportion of interior habitat to edge habitat decreases and species adapted to the interior habitats decline, reducing overall species diversity (Dale and others 2000). Large decreases in habitat patch size or increased distance between habitat patches can both reduce or eliminate populations using those habitats and alter ecosystem processes (Dale and others 2000). Also, as interior habitat shrinks, edge-adapted predators have proportionally greater access to interior prey species. Species adapted to edge habitats or that require small habitat areas are able to survive in a matrix of small patches; examples in the City of Portland include coyote and purple finch. Interior-adapted species are less common in Portland but include brown creeper and Douglas' squirrel. (See Metro's Goal 5 report [Metro 2002a] for a more complete discussion of patch size and edge effect.)

Upland habitat in urban areas often is fragmented and intermingled with developed urban land uses (Metro 2002a). It is crucial that upland habitats have some degree of connectivity to aquatic and riparian habitats and to other upland habitat patches. Connections to upland habitat also are important where riparian buffers are not wide enough to meet all of the needs of a species. In a fragmented landscape, habitat corridors can provide connectivity between habitat patches and surrounding, less developed landscapes.

Although corridors foster connectivity of habitats, in some cases they can allow exotic plant and animal species to invade native habitats. (See Metro's Goal 5 report [Metro 2002] for a more complete discussion of habitat corridors and connectivity.)

Implications. As the City comes to understand the site- and basinwide-scale linkages among the physical and temporal dimensions of the ecosystem, it will be important to begin coordinating across scale and across jurisdictions. It is well understood that upstream actions affect downstream jurisdictions such as the City of Portland. If rivers and their lateral floodplain components are reconnected, the associated fundamental physical processes can be used to solve long-standing flooding problems; such reconnections restore many physical and biotic functions in riverine, wetland and upland habitats.

Johnson Creek is an example of the floodplain being intentionally cut off from the stream through channelizing and diking so that flood waters could move through the basin as quickly as possible. As the City has come to learn more about the important functions of floodplains, it has realized that disconnecting floodplains can come at a cost. Reconnected floodplains can result in benefits such as storage and flood attenuation as well as the provision of off-channel habitat for ESA-listed salmonids. Restoring these riverine functions also allows wildlife such as beaver to provide additional functions and habitat that further enhance conditions for fish and wildlife species.

Allowing floods to access historical floodplains will create important physical habitat features that are difficult to create in other ways. Examples of such features are side channels or off-channel pools formed by ascending and then receding flood flows. To allow this to occur in the midst of a crowded urban setting will require careful engineering so that flood forces can access floodplains in a managed and controlled manner. The possibility of returning beaver functions to the floodplain also needs to be addressed to avoid possible conflicts with humans.

Riverine, Wetland and Ecology Principle 3: Hydrologic modification and changes in upland land use can reduce habitat diversity, decrease native biodiversity, increase nonnative species and exacerbate water pollution, landslides and flooding.

Hydrologic and ecological processes and functions link rivers and their biota to their watersheds and downstream waterbodies. As the hydrologic cycles of rivers have been modified, rivers have become degraded. This happens because changes in the hydrologic character of a watershed have acted to reduce the size and complexity of the riparian "fringe" between rivers and uplands, which in effect impairs the hydrologic and ecological links between the aquatic and terrestrial ecosystems. The foundation for understanding current conditions and planning future actions must begin with the recognition of the causes and consequences of hydrologic modification to streams and rivers.

Causes of Hydrologic Modification

Modification of water pathways in a watershed occurs through alteration of all major stages of the hydrologic cycle, including evapotranspiration, throughflow, overland runoff and groundwater recharge. This in turn modifies the ecological processes and functions. In large rivers this modification occurs through flow regulation from dams and reservoirs and the filling and diking of floodplains. In smaller, urban streams, the filling of floodplains and increase in impervious surfaces reduces the watershed's permeability and compacts soils, reducing evapotranspiration, groundwater recharge and throughflow. Upland land uses can have a major impact on both large and small urban streams.

Effects of Hydrologic Modification

Hydrologic modification can reduce habitat diversity by severing the connections among the channel, groundwater, floodplain and upland components of the watershed; causing habitats for riverine biota to become spatially homogenous and limited to the permanently wetted portion of the channel thalweg; and increasing the amount of impervious surfaces in the landscape, thus causing a net decrease in groundwater recharge and net increase in surface water runoff after storms. These effects are discussed below.

Effects of Flow Regulation in Large Rivers. Flow regulation via storage dams and reservoirs is the most pervasive change introduced to large rivers throughout the world (Stanford and others 1996). In large rivers, reservoir storage of peak flows for flood control, navigation, irrigation and hydropower production can sever the ecological connectivity between upstream and downstream reaches and among channels, groundwater and floodplains. This, in turn, often reduces native biodiversity and productivity or allows nonnative biota to proliferate.

More specifically, severing the river continuum can have the following effects:

- Flood peaks are eliminated.
- Daily discharges are more variable, and temperature seasonality may be altered (Stanford and Hauer 1992, Blinn and others 1995).
- The mass transport of water and materials, which are important in the creation of instream and floodplain habitats for riverine biota, is drastically changed.
- Storage of bedload in the reservoir and the constant flushing of clear water downstream artificially deplete gravel and finer sediments in the tailwaters, causing the riverbed to be armored with large cobbles and boulders.
- The amount of floodplain wetland is reduced, which reduces the diversity and viability of species that depend on wetland structure and functions.

Flow regulation can increase baseflows substantially and produce flows that fluctuate so erratically that aquatic biota cannot survive in shallow, near-shore habitats. Peak flows can be insufficient to scour and transport the largest material downstream. With a loss of scouring flood flows and upstream sediment supply, the channel erodes downward, the former floodplain is subject to less flooding and riparian vegetation invades the channel in depositional reaches. The result is habitat simplification and constriction of the channel.

Many restoration actions taken at a particular reach fail to meet objectives because the local effects of flow regulation, which include changes in floodplain inundation and the amount of sediment and wood being supplied from both upstream and upland areas, have caused the river system to become disjointed; the river is no longer functioning as an interconnected ecosystem across the watershed or from headwaters to ocean confluence (Independent Scientific Group 2000). When the dynamic interactive pathways of the river continuum are severed or compromised, the capacity of large river ecosystems to sustain natural biodiversity is reduced.

Restoration actions may not meet objectives unless rivers are viewed as interconnected ecosystems that extend from their headwaters to the ocean.

Effects of Hydrologic Modification in Urban Streams. In urban streams, the quantity of physical habitat has been reduced temporally and spatially. Tributary density is reduced through paving, piping and draining as land is developed (Steedman 1987). This effect occurs predominantly in first- through third-order streams and results in a disruption of the riverine-headwater pathway (the longitudinal dimension within a watershed). Because many headwater tributary streams play a role in maintaining stable levels of discharge within a watershed, and because they provide significant spawning and rearing habitat for many fish species, the loss of these systems greatly affects species diversity, the densities of individual species and, ultimately, the productivity of the river (Imhoff and others 1991).

The interactions of the river and its floodplain also are severely impaired by urbanization. During certain times of the year, the biota of rivers rely on the interconnection of the river and its floodplain complex of side channels, backwater areas and wetlands for spawning and rearing habitats (Welcomme 1979, 1985, Sedell and Frogatt 1984, Bacalbasa-Dobrovici 1989, Fremling and others 1989, Lelek 1989). When the river-floodplain pathway is decoupled, productivity and species diversity are fundamentally reduced (Halyk and Balon 1983, Welcomme 1985, 1988; Regier and others 1989).

Effects of Impervious Surfaces. In smaller urban streams, impervious surfaces modify hydrologic pathways. As the amount of impervious surfaces increases, there is a net decrease in groundwater recharge and a net increase in surface water runoff after storms (see Figure 2-2). The following process is typical:

1. Increased stormwater flows change the physical equilibrium of the stream channel morphology. As a greater percentage of stormwater flows into the channel via curbs, gutters, and storm sewers (instead of percolating to groundwater), peak stream flows increase, as does the discharge of sediments into the stream.
2. Larger peak flows alter the river's channel width, depth, sinuosity, bedload transport, bed armoring, down-cutting, riffle-pool sequencing and connection to floodplains.
3. The stream channel is structurally simplified to the point that it lacks the stability and physical diversity to support complex aquatic and wetland communities (Imhoff and others 1991).

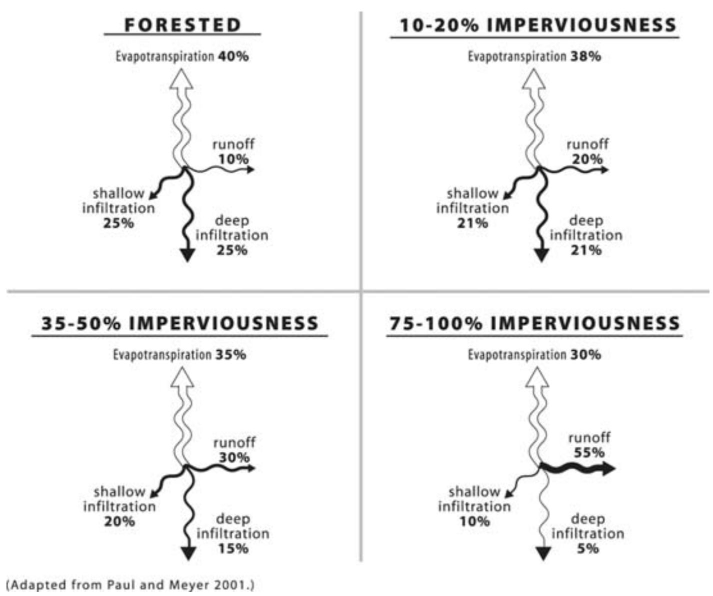

FIGURE 2-2
Changes in Hydrologic Flows with Increasing Impervious Surface Cover in Urbanizing Catchments

The ecological principles that emerge from this evidence have been corroborated in the growing literature on the ecology of flow-regulated rivers and urban streams affected by impervious surfaces (reviewed by Baxter 1977; Ward and Stanford 1979, 1987; Lillehammer and Saltveit 1984; Petts 1989; Booth 1991; Calow and Petts 1992; Schueler 1994; May and others 1997).

Effects on Groundwater. Reduction in groundwater recharge is another possible effect of hydrologic modification and can have profound effects on river productivity. When infiltration within a watershed is reduced, so too is the recharge of shallow aquifers and wetlands that control and moderate baseflows in adjacent streams. Although the repercussions of increasing surface water runoff are relatively well known, the impacts of reducing groundwater infiltration are less well understood. There is evidence that increasing surface water runoff within a watershed from reductions in infiltration affects baseflow (Hammer 1972, Klein 1979, Steedman 1987). The implications of this are serious because it is baseflow that ultimately controls the maximum potential productivity of a river system, through control of critical living space for fish and aquatic wildlife and native plant communities during the productive summer months.

Reduction in Native Biodiversity and Proliferation of Nonnative Species. The modification of hydrologic regimes and the associated severing of connectivity in the three spatial dimensions of landscapes have reduced both habitat diversity and the biodiversity of native species and contributed to the proliferation of nonnative species. The altered temperature patterns, continual export of very fine organic matter and dissolved nutrients, simplification of channel morphology, stabilization of the bottom substratum and loss of floodplain inundation that can result from hydrologic modification promote environmental conditions to which native species are poorly adapted, giving nonnative plants and animals the opportunity to establish robust populations (Stanford and Ward 1986, Li and others 1987, Pflieger and Grace 1987, Bain and others 1988, Shannon and others 1994).

In an urban environment, competition from nonnative plant and animal species is second only to habitat loss as a cause of native species decline (Defenders of Wildlife 2003). Urban development inherently brings opportunistic weeds, including landscape "escapees" and roadside-adapted species. Ecosystem management requires an emphasis on native species, as they are best adapted to the local climate and ecological conditions.

Native species are consistently more abundant in unmodified rivers and streams than in modified rivers and streams.

Nonnative invasive species often have negative effects on native flora and fauna and the functioning of ecological systems, displacing native vegetation and threatening the wildlife that depend on them (Dale and others 2000). Introduced species often find no natural enemies in their new habitat and therefore spread quickly and easily. In the Portland area, English ivy, Himalayan blackberry and the European starling are notorious invasive species that have displaced native wildlife and vegetation. Other, less invasive nonnative species may provide habitat value that is less than a fully functioning native ecosystem would provide but that is still significant. The City should simultaneously encourage native species and discourage nonnatives when possible, while recognizing that in an urban environment much of the functioning habitat will be provided and occupied by nonnatives.

Additional Effects of Hydrologic Modification. The uncoupling of the three spatial dimensions through hydrologic modifications simplifies the structural diversity of rivers, wetlands and uplands. A river's physical diversity and the biotic communities it sustains, from bacteria to fish, contribute to its ability to assimilate and process nutrients and other materials (Imhoff and others 1991). Therefore, rivers and their biotic communities exert a certain amount of "top down" control on water quality as long as inputs from the terrestrial component of the watershed are not so concentrated as to have a toxic effect on the aquatic community.

In open waterways nutrients circulate through a water column and downstream depending on instream flow dynamics. This dynamic process of nutrient transport in rivers is termed "nutrient spiraling" (Imhoff and others 1991) and varies depending on site-specific and reach-specific flow conditions. For example, headwater streams often have turbulent flows and a high degree of mixing throughout the water column. In flow conditions such as these, nutrients entrained in the water column are readily available to algae, plants, invertebrates and fish. Conversely, in large, deep rivers such as the lower mainstem reaches of the Columbia and Willamette rivers, throughflow—in the form of nonturbulent, roughly horizontal layers—is more characteristic. Although turbulent flow does occur within the water columns of large rivers, turbulent flow does not span the depth of the water column. Under these flow conditions, aquatic vegetation and organisms that occupy perimeter habitats do not absorb nutrients entrained in the water column as readily. Rather, nutrients remain in solution, and their fate is determined by downstream riverine and estuarine hydrologic and hydraulic conditions.

The concept and implications of nutrient spiraling have been discussed for many years in the scientific community (Newbold and others 1981, Elwood and others 1983) in the context of carbon or nutrient flow down a stream channel. But the concept of nutrient spiraling can also be used to illustrate the temporal and spatial mechanisms of nutrient and carbon capture and entrainment in living tissues (Odum 1969, Imhof and others 1991).

For example, the amount of nutrient spiraling and entrainment varies from stream to stream based on the particular stream's relative physical and biotic complexity, which is usually linked to the stream's physical diversity and stability. In theory, the more physically complex a river system, the greater its potential to process nutrients in a manner that maintains water quality by achieving a reasonably stable balance between aquatic productivity and consumption. The corollary of this is that the simpler the physical structure of a river, the poorer the ability to process nutrients, leading to unstable aquatic productivity and consumption. For urban streams, this frequently results in diminished water quality as a result of excessive nutrient and organic matter loads, originating mainly from external sources.

This hypothetical process may explain why many damaged and simplified streams exhibit relatively poor water quality, despite attempts to control point sources of pollution. It implies that the restoration of structural complexity in the stream channel—such as by creating fish habitat in urban areas—could help improve water quality (Imhoff and others 1991).

Effects of Wetland Loss. Human activities have had a large impact over the years on wetland habitat (including riparian areas) and wetland functions in the Portland urban area. The rate of aerial loss of wetlands has declined with the passage of the Clean Water Act and its amendments in the 1970s, but the reduction in wetland functions continues in the wetlands that remain (U.S. Fish and Wildlife Service 2000).

Metro (2002a) presents a detailed discussion of the impacts of urbanization on wetland and riparian habitats and function. This discussion of the effects of wetland loss includes, but is not limited to, converting, altering, and fragmenting habitat; filling or loss of wetlands; reducing biodiversity and rare or specialist species; and contaminating wetlands with a variety of chemicals. Human activities away from wetlands (in the longitudinal and lateral dimensions of the watershed) also can result in the loss of wetland area and function, although such losses often occur more slowly and are not as obvious as discrete actions such as fills. Examples of how human activities away from the wetlands can cause wetland loss include the following:

- Upslope erosion settling out in wetlands, potentially filling them; instream dams inundating wetland vegetation
- Collection of stormwater in uplands, which can reduce the area contributing runoff to wetlands and thus the amount of infiltration into them
- Increased impervious surfaces in uplands, which alters peak and base flows to wetlands
- Increased amounts of herbicides, pesticides, oil and grease from upland development entering wetlands.

Wetlands are the connecting link between riverine and upland components of the watershed. This connecting link facilitates many fish and wildlife interactions (beaver and coho, for example) and hydrogeomorphic functions (Adamus 2004). When these connections are lost as a result of urbanization, the impact on the adjacent riverine environment is obvious to fisheries biologists, who recognize the importance of off-channel wetlands to many species of fish and other aquatic biota that use backwater habitats, such as rearing juvenile salmon. Loss of wetland connection to upland habitats is also obvious to wildlife biologists but less understood by the general public. McGarigal and McComb (1992 and subsequent papers) document the importance of upland habitat to the diversity of birds in streamside habitats and promote landscape-level management actions that consider both streamside and upland habitats. McGarigal and McComb’s recommendation based on bird studies also makes sense for species such as the western pond turtle that require wetland areas for rearing and upland areas for nesting functions (Spinks and others 2003).

The loss of connectivity (that is, fragmentation) along riparian systems and between riverine, wetland and upland habitats is particularly adverse for less-mobile species such as reptiles, amphibians and small mammals (Bolger and others 1997). Bolger and others (1991) found that local extinctions in isolated habitats were common and that recolonization of isolated habitats was rare.

Effects of Upland Loss. Metro (2002a) provides a detailed discussion of the adverse impact of urbanization on upland habitat, with impacts including loss of habitat, fragmentation and disturbance. The fragmentation of upland habitat that accompanied Portland’s population growth has left several areas of unique habitats associated with buttes, cliffs, isolated sloughs in floodplain and steep-slope ravines in locations that are less desirable for development. Wildlife associated with these remnant habitats are a subset of the species normally expected in west-side forests (Ferguson and others 2001), and these remnants may play an important role in maintaining native biodiversity.

As land continues to be developed in the urban environment, the once-dominant west-side coniferous habitat slowly is becoming rare itself. This slow loss of the west-side forest has several consequences: the increasing scarcity of what once was an abundant resource, the loss of upland matrix habitat to connect unique habitats (such as domes and isolated sloughs) that remain from development, and the loss of ecosystem functions (such as nesting and decaying logs) in wetland and riverine habitats. But the loss of mature forest and conversion of upland habitat to agriculture and urban development in the Portland area has also resulted in the loss of ecosystem functions in the uplands that can best be understood by considering the cumulative impact over time. Flinn and Velland (2005) document the loss of plant and animal diversity in post-agricultural landscapes and suggest that current habitats show much reduced species richness and altered composition compared to forests that were never cleared. Furthermore, Flinn and Velland (2005) suggest that post-agricultural habitats depress colonization by plants and animals and that the diversity required to support adequate dispersal may take centuries to restore. Lost functions such as those provided by downed wood in the urban environment may not even be desirable because of the potential for fuel loading and the threat of fire. Just as a properly functioning hydrograph is important to riverine restoration, it is important to understand the upland functions that have been lost in the urban ecosystem when assessing the desirability and feasibility of restoring upland habitats or connecting upland and wetland patches.

Disturbance of upland vegetation and wildlife in the urban environment is a multi-faceted problem, encompassing nonindigenous species, roadways and other developments and human intrusion into sensitive areas. The fact that herbicides and pesticides are used in an attempt to control nonindigenous species—especially in the upland urban environment—illustrates that a solution for one problem can, especially if used improperly, lead to another, such as contaminated stormwater runoff to streams and wetlands. Roads, a necessary component of the urban environment, result in the loss of habitat, prevent dispersal that is important to the life cycle of many upland species, and are a source of road-related chemicals that often are transported to riverine, wetland and upland environments. Innovative solutions to road-related losses are being studied by the University of Wisconsin (see www.deercrash.com). Disturbance in urban environments also includes human intrusion into sensitive areas; this results in trampling of vegetation, noise and litter. Hennings (2001) and others document that certain wildlife species (Stellar's jay, for example) are especially vulnerable to human disturbance in the urban environment. At the same time it is encouraging that other species such as the bald eagle and the peregrine falcon, which were once rare in the urban landscape, now occur within the City limits.

Implications. Modification of historical flows and changes in upland land use can have many unintended and deleterious effects, as has been described above. Many of the actions taken historically by the City were without full knowledge or appreciation of their cumulative effects and consequences, many of which the City of Portland is now having to deal with (combined sewer overflows, flooding in Johnson Creek, declines of native fish and wildlife species and so on). In wetland and upland areas, the habitat loss and fragmentation associated with land use changes have impeded the dispersal of native plants and animals, decreased colonization of isolated habitats and reduced native biodiversity.

To solve these problems, actions will have to be implemented within a broad context that includes working across disciplines and with multiple objectives. Collaborative efforts must be made with an understanding of the size and distribution of upland habitat patches and the terrestrial species that do, or could potentially, depend on them; the effects of upstream actions on rivers and streams; and the impact of modifications of riverine, wetland and upland habitats. Without such understanding, efforts to achieve healthy watersheds that include healthy biological communities are unlikely to succeed. Efforts must be effective at both the site and watershed scales, as well as across jurisdictions.

Salmonid Ecology Principles

The *Framework* includes scientific principles related specifically to salmonids because, as ESA-listed species, salmonids are subject to certain legal protections; their health, abundance and productivity reflect many key watershed processes; and they have special cultural and economic significance in the region. Salmonids and river ecosystems co-evolved in response to dynamic processes that occur in the three spatial dimensions described earlier. In this context, three principles emerge that describe salmonid life history and habitat relationships.

Salmonid Ecology Principles

1. Life history diversity, genetic diversity and metapopulation organization are ways salmonids adapt to their complex and connected habitats and are the basis of salmonid productivity and salmonids' ability to cope with environmental variation.
2. Sustained salmonid productivity requires a network of complex, diverse and interconnected habitats that are created, altered and maintained by natural physical processes in freshwater, estuarine and ocean environments.
3. Restoration of salmonids must address the entire natural and human ecosystem, encompassing the continuum of freshwater, estuarine and ocean habitats where salmonids complete their life histories.

Salmonid Ecology Principle 1: Life history diversity, genetic diversity and metapopulation organization are ways salmonids adapt to their complex and connected habitats and are the basis of salmonid productivity and salmonids' ability to cope with environmental variation.

Salmonid habitat has been described as a "chain of favorable environments connected within a definite season in time and place, in such a way as to provide maximum survival" (Thompson 1959). This "chain" can be thought of as temporal and spatial "pathways" through the freshwater, estuarine and marine ecosystem that salmon use (Independent Scientific Group 2000). Salmonids follow particular pathways, exhibiting unique life history patterns that reflect the salmonids' responses to problems of survival and reproduction. Life history diversity in salmon can be described as the variable use (in terms of time and space) of the chain of available rearing and migrating habitats (Lichatowich and others 1995).

Diverse life history patterns dampen the risk of extinction or reduced production in fluctuating environments (Den Boer 1968). The potential and realized life histories of a population theoretically reflect adaptive capacity—the ability to survive in fluctuating environments.

Spatial and temporal habitat diversity is critical for expression of life history diversity. Habitat degradation, hydrologic modification and the loss of connectivity among habitats has constrained production and suppressed expression of life history diversity within the Willamette River basin, its watershed and its tributaries.

Features of salmonid life histories include such phenotypic[3] traits as age at maturity, mortality schedules, size and growth (Stearns 1976). Salmonid life history traits also include age and size that juveniles migrate within the river system or to the sea, growth and maturity during riverine and lacustrine migrations, spawning habitat preferences, emigration patterns, and age and timing of spawning migration. Salmonids that make use of different chains of interconnected habitat may exhibit variation in important life history traits, such as the age at which juveniles migrate to the sea, the timing of spawning migration and spawning habitat preferences. In several instances multiple life histories have been observed within a single river system (Reimers 1973, Schluchter and Lichatowich 1977, Carl and Healey 1984, Gharett and Smoker 1993, Lestelle and Gilbertson 1993). In the Willamette River ecosystem, life history diversity would be expected to be substantial owing to the ecosystem's large size and number of tributaries, highly variable flow regime, and complex geomorphology, which affects all watersheds in the ecosystem.

For example, in salmon, phenotypic diversity is exhibited over a broad geographic scale in the stream and ocean life history types (Healey and Prince 1995). Stream-type Chinook migrate to sea in the spring of their second year in freshwater, whereas ocean-type Chinook migrate to sea in their first year, usually within a few months of emerging from the gravel (Healey 1991). Stream- and ocean-type fish also differ in other aspects of their life histories, such as oceanic distribution and timing of adult migration (Healey 1991).

Stream and ocean life histories are major life history themes, but within each theme, juvenile migration patterns vary. Continual downstream migration through the lower mainstem of rivers by ocean-type Chinook salmon throughout most of the spring and fall (Rich 1920, Beauchamp and others 1983, Nicholas and Hankin 1988) may represent several discrete migrations of juveniles from different locations in the watershed (Rich 1920). What appears to be a single continuous migration of ocean-type juvenile Chinook salmon may in fact be a diverse assemblage of groups of salmon following somewhat different habitat pathways and thus having somewhat different life histories. Migration patterns also vary among stream-type juvenile Chinook salmon that migrate to the sea in their second year. Some stream-type Chinook salmon remain in headwater areas to rear, while others move into downstream mainstem areas to rear during the winter (Healey 1991).

Steelhead juveniles undergo physiological smoltification within a wide range of ages (from two to seven years) and sizes, depending on population structure, genetic expression and environmental conditions such as temperature, flow and habitat productivity. Some juveniles spend their entire freshwater rearing cycle in their natal stream, while others

[3] Of, or relating to, the visible or behavioral properties of an organism that are produced as a result of the interaction of the genotype and the environment.

emigrate to lower and more productive river reaches as they grow and require more sustenance.

Before flow regulation and extensive habitat modification, complex and interconnected habitats were created and maintained in the Willamette River basin through natural riverine processes. The availability of these habitats facilitated the expression of life history diversity and contributed to maintaining the production of salmonids. Adaptation of individual populations to specific habitats (and life history pathways) across a mosaic of different landscapes created a diversity of populations that characterized salmonid fishes in the Willamette River basin. Today much of that diversity has been lost as a result of modification of flows and degradation of both mainstem and tributary habitats.

Two additional concepts further elaborate the connections between salmon life histories and riverine habitat: patch dynamics and salmonid metapopulations.

Patch Dynamics. On a watershed scale, salmon habitat can be viewed as a system of "patches," with fish moving among patches for the purposes of rearing, seeking refuge, migrating to spawn (adults) or migrating to the ocean (juveniles) (Murphy and others 1997). In theory, the type of habitat patches varies along the river continuum, corresponding to physical and biological variables, so that the specific types of habitat patches needed at different life stages are distributed in a nonrandom manner. The patches may include spawning areas for adults and a series of spatially and temporally connected areas for summer feeding and winter refugia.

A mosaic of heterogeneous habitats supports species diversity, while a variety of channel and floodplain structures creates a mosaic of habitats for the myriad of plants and animals that make up riverine food webs. The resources needed by an organism at a particular stage in its life history are distributed discretely, in "patches," within this heterogeneous landscape. As flows change seasonally, so does the ability of water to move sediment, gravel, wood and other material. Therefore, to be successful, biota must adapt to resources located in an array of dynamic patches that exist from the local scale (such as in a deep pool downstream of a large boulder in a particular river reach) to the watershed scale (Townsend 1989). As biota attempt to find and use these patches to sustain growth and reproduction over the long term, they must also adapt to the physical forces of water movement (Statzner and others 1988). Therefore, biota are often arrayed in particular locations within the river channel and along the river continuum (Poff and Allen 1995).

A fundamental challenge is to establish quantitative links between the variation in a species' life-history requirements and the variation over space and time in conditions along the river (Schlosser 1991). Because Pacific salmon migrate extensively in marine and freshwater, they are seasonally distributed across a vast ecosystem composed of a chain of favorable geographic habitats (Thompson 1959). A major consequence of land management practices and development in the riparian zone, floodplain and land margins has been the simplification and fragmentation of salmon habitat (Reeves and Sedell 1992). Simplification is a reduction in the number and kinds of habitat types, a decrease in structural materials that make up salmon habitat, such as large wood, and a decline in the indicators of water quality, such as temperature (McIntosh and others 1993). Habitat simplification reduces the number of habitat types, and fragmentation disrupts connectivity and species' ability to migrate at the appropriate time between links in the habitat chain (Lichatowich and others

1995). Even where favorable habitats are retained in undeveloped portions of watersheds, fragmentation may cause those habitats to be inaccessible at the time they are needed by a particular species.

Salmonid Metapopulations. The National Research Council (1996) recommends that salmon be viewed as metapopulations rather than isolated stocks or populations. The Independent Scientific Group (2000) defines metapopulations as groups of local populations linked by individuals that stray from one population to the next, thus facilitating gene flow into larger regional populations that may encompass an entire watershed (Hanski 1991, Hanski and Gilpin 1991). In other words, a metapopulation is a collection of populations in geographical proximity to one another that have a history of interactions via straying and genetic exchange.

Salmonids organize into metapopulations because they display high fidelity in homing to their natal streams (Helle 1981), which allows them to establish local spawning populations. In addition, salmon have relatively low but variable levels of straying (Quinn and Unwin 1993), which creates opportunities for recolonization of habitats where local extinction has occurred. The spatial arrangement of large- and small-scale habitat features within a catchment may serve as a guide for metapopulation organization of fish species (Schlosser and Angermeier 1995).

Metapopulation structure most likely influences the probability of persistence for a species. Metapopulation linkages allow for local extinction of populations that subsequently can be reestablished via colonization from adjacent populations. Recent work suggests that salmonid metapopulations resemble core-satellite metapopulations (Rieman and McIntyre 1993, Li and others 1995, Schlosser and Angermeier 1995). Core populations serve as important sources of colonists that could both reestablish satellite populations in habitat where extinctions have occurred (Harrison 1991, Schoener 1991, Rieman and McIntyre 1993, Harrison 1994, Schlosser and Angermeir 1995) and sustain populations that have been severely depleted. The proximity of populations and favorability of connecting habitats can affect the exchange of individuals between local populations and thus influence the potential for recolonization of habitats where local extinction has occurred. Thus, core populations can buffer metapopulations against environmental change and contribute to the resiliency of regional salmonid production (Independent Scientific Group 2000).

It is likely that spawning populations that could have functioned as core-like populations occurred historically in alluvial segments with well-developed floodplains and gravel bars (Stanford and others 1996). These areas provide a complex habitat mosaic highly suitable for spawning, incubating eggs and rearing juveniles and may have served as centers of habitat stability (Independent Scientific Group 2000).

Implications. The following principle that guided the City, the National Marine Fisheries Service in the National Oceanic and Atmospheric Administration (NOAA Fisheries) and other agencies and stakeholders in the June 1999 “State of the Science on Fish Ecology in Large Low-Gradient Rivers” workshop (City of Portland 1999) helped to determine the City’s role and responsibilities regarding salmon listed under the Endangered Species Act:

> *Complex life history strategies of salmon are a result of evolutionary adaptations to physical, chemical and biological diversity resulting from water and floodplain interactions occurring over a long period of time in the lower Willamette River.*

By investigating a series of hypotheses, workshop participants determined that salmon (particularly juveniles) should be expressing rearing strategies in the lower Willamette. Participants also concluded that, to meet the City Council's resolutions to contribute to the recovery of salmonids (Resolution 35715), research should be conducted to understand more about juvenile salmon behavior in the lower river. The Willamette Fish Study, a four-year fisheries research investigation of the lower Willamette River by the City and ODFW, was the main outcome of these discussions.[4]

The study identified complex behavioral expressions among different species of salmon and among different age classes within the same species; additional studies are needed to understand how and where limiting factors occur. For example, it is important to understand how salmonids are surviving as they migrate through and rear in the vicinity of Portland. Because the City is an important location through which all anadromous salmonid populations that use the Willamette River basin must pass, it will be important to try to understand whether impacts from City activities may limit their survival. Given the importance of this effort, agencies with authority over salmon, water and habitat should be brought in as partners in the Willamette Fish Study.

Salmonid Ecology Principle 2: Sustained salmonid productivity requires a network of complex, diverse and interconnected habitats that are created, altered and maintained by natural physical processes in freshwater, estuarine and ocean environments.

The importance of a complex and dynamic continuum of habitats in a system such as the Willamette River is a central tenet of the scientific foundation. The river continuum concept describes a complex, continuous dynamic gradient of habitat from headwaters to oceanic confluences (Vannote and other 1980). The river provides salmon with access to freshwater, estuarine and ocean environments and associated diverse and high-quality habitats that are crucial for salmonid spawning, rearing and migration; maintenance of food webs; and predator avoidance. Ocean conditions vary and can significantly affect overall patterns of salmonid productivity from year to year.

Connections along the continuum also are important. For example, downstream communities or populations may benefit from activities of populations higher in the watershed, such as the breakdown of leaf litter by aquatic insects living upstream.

Historically, alluvial floodplain reaches have been arrayed along the river continuum between valley segments like beads on a string. These reaches appear to function as centers of biological and physical organization within the continuum (Regier and others 1989). They are likely to be nodes of production and biological diversity that are structurally and functionally linked by the river corridor (Copp 1989, Gregory and others 1991, Zwick 1992, Stanford and Ward 1993, Stanford and Ward 1995). According to the Independent Scientific Group (2000), floodplain reaches and gravel-cobble bedded mainstem segments are

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[4] The Willamette Fish Study is an investigation of how juvenile salmonids are using the variety of bank treatments and near-shore developments in the lower Willamette River. The study began in 2000 and is being conducted by ODFW on behalf of the City of Portland.

particularly important in the Columbia River basin because habitat diversity and complexity are greatest in those locations.

Each species or unique life history type (meaning a stock or population) is most abundant where the resources it requires are most abundant and/or can be obtained most efficiently. Species will be present (and locally adapted) wherever they have enough resources to sustain their growth and reproduction. For some species, resources are available such that the species can maintain its life history without needing to move very much; this results in suites of organisms occurring in zones along the river continuum. Other species have developed adaptations that involve migrating long distances in search of the resources needed at each life stage. In the case of anadromous salmon and trout, this includes migrations to downstream reaches, estuaries and eventually the ocean.

Critical habitats for the various life stages of salmonids need to be interconnected in three important spatial dimensions:

- **Longitudinal (or riverine)**—a continuum of runs, riffles and pools of varying geometry from the headwaters of a river to its mouth
- **Lateral (or riparian)**—an array of habitats from the middle of the main channel through various side and flood channels and wetlands to floodplains and the uplands of the valley wall, including streamside vegetation and associated faunal assemblages
- **Vertical (or hyporheic)**—a lattice work of underground habitat associated with the flow of river water through the alluvium (bed sediments) of the channel

These spatial dimensions correspond to the spatial and temporal dimensions that link watersheds and riverine ecosystems.

Implications. A great amount of effort has been put into controlling the unpredictable nature of flows in major urban centers such as Portland that have been built along rivers and streams. Flow control efforts have included flood control (dams and reservoirs), draining and filling floodplains, and creating hardened bank structures (rock, riprap and seawalls). This has had additional consequences such as the reduction or complete elimination of the habitat-forming processes of flooding that salmonids require for rearing.

To meet the multiple physical and temporal life history needs of salmon that traverse a large geographical area, agencies and jurisdictions must coordinate their restoration efforts. The science of restoration is still in its developing stages. Several papers have raised the issue that watershed and salmonid restoration requires restoring natural processes that create and maintain habitat (Frissel and Nawa 1992) (Roni and others 2002). Much of what constitutes restoration today occurs at the site-specific scale because most jurisdictions, such as Portland, have limited authority to operate outside of their geographical boundaries.

While it can be argued that many limiting factors and bottlenecks can and must be dealt with at the local level, unless watershed-scale processes such as natural seasonal flows are restored, many of the site-specific approaches are at risk of failing (Frissell and Nawa 1992) or of not adequately addressing the fundamental problems at the appropriate scale (Beechie and Bolton 1999).

Thus research and decision making must be designed to work at both the site-specific and watershedwide scales. Only by understanding the limiting factors operating to reduce the diversity and interconnectedness of habitats at both the local and regional scales, and being able to coordinate effective responses at all of these levels, will watershed, river and salmon restoration occur.

Salmonid Ecology Principle 3: Restoration of salmonids must address the entire natural and human ecosystem, encompassing the continuum of freshwater, estuarine and ocean habitats where salmonids complete their histories.

The salmon-bearing ecosystem is characterized by processes that create and maintain a complete array of habitats in which fish species grow and reproduce. Complex habitats with a high degree of spatial and temporal connectivity permit the development and expression of life history diversity, which is an essential component of salmonid productive capacity. Salmonid restoration implies reestablishment of life history diversity, which requires establishment of habitat diversity and connectivity.

Depleted populations of native salmonids cannot be expected to rebuild if any of the habitats required for successful completion of all life stages are compromised. For example, freshwater habitats must provide flow, food and cover for rearing; estuarine environments must allow for continued smoltification and feeding without amplified predatory threats; and the ocean environment must provide opportunities for feeding and migration. In addition to having intact environments that support different stages of salmonid rearing, habitats must be accessible and connected. Thus regionwide restoration efforts must consider the entire life cycle and complex habitat needs of salmonids, or populations will continue to decline over their geographic range.

Although challenging, restoration of salmonids in urban or urbanizing watersheds is feasible if essential ecological processes and conditions exist. The Independent Scientific Group (2000) based many of its tenets on the assumption that an ecosystem that contains a mix of natural and cultural features that typifies modern society can sustain all life stages of a diverse suite of salmonid populations if it provides essential ecological processes and conditions. The Independent Scientific Group referred to this as a “normative” ecosystem. The region, through its policy representatives, will have to decide on the degree to which it improves conditions for salmon (and other species), based on economic and cultural values. Progress toward the restoration goals stated in the introduction to this document requires moving the system from its current degraded state to one that supports improved watershed processes and conditions for salmonids.

The City recognizes that its urban makeup significantly constrains the level of watershed health that it is practical to achieve and sustain. It is not realistic to expect urban-area watersheds to provide the same level of ecological function as a pristine, undisturbed watershed. Nevertheless, Portland’s watersheds provide important habitats for fish and wildlife species, and the City believes that essential ecological functions and processes needed to sustain these biological communities can be maintained or restored in these

Although urbanization constrains the level of watershed health that can be achieved and sustained, Portland’s watersheds are capable of providing essential ecological functions and processes needed to sustain biological communities.

watersheds. Restoration guidelines for achieving these ends are described in detail in subsequent sections of this chapter.

While it is NOAA Fisheries, the U.S. Fish and Wildlife Service (USFWS) and ODFW that have management authority over salmonid populations, the City of Portland does maintain authority over land use decisions that affect habitat and ecological processes through planning, permitting and enforcement. NOAA Fisheries has indicated that while habitat characteristics are not part of the viability criteria it will establish for salmonid recovery (see Appendix E), the effects of habitat characteristics are ultimately reflected in four population parameters for which NOAA Fisheries is setting viable salmonid population criteria: abundance, productivity, spatial structure and diversity (McElhany and others 2000). For example, NOAA Fisheries recognizes that habitat structure largely dictates a population's spatial structure. The City agrees with NOAA Fisheries' assessment and believes that viable salmonid populations can be sustained in the lower Willamette by restoring and protecting habitat functions and processes consistent with a mix of natural and cultural features typical in urban watersheds.

Implications. It is important to recognize and account for the significance of salmon not only as a commodity resource to be harvested for human consumption, but also for salmon's crucial role in supporting overall ecosystem health. Salmon act as an ecological process vector, important in the transport of energy and nutrients among the ocean, estuaries, and freshwater environments. The flow of nutrients back upstream via spawning salmon and the ability of watersheds to retain those nutrients plays a vital role in determining the overall productivity of salmon runs.

As a seasonal resource, salmon directly affect the ecology of many aquatic and terrestrial consumers, and indirectly affect the entire food web. Likewise, many species of wildlife, such as bald eagle, river otter and beaver, play key roles in providing for the health and sustainability of the ecosystems upon which salmon depend. As the health of salmon populations improves, increases in the populations of many of the associated wildlife species also would be expected. Salmon and wildlife are important codependent components of regional ecosystem biodiversity (Cederholm and others 2000).

Salmon life history strategies cover a broad geographic scale, reaching well beyond the City of Portland's jurisdiction. To ensure that the City's actions are effective, a framework for coordinating activities at both local and basinwide scales must be implemented. Regionwide planning efforts that are effective at communicating and coordinating with local jurisdictions will be necessary. NOAA Fisheries' Technical Recovery Team's planning at the evolutionarily significant unit (ESU) scale and the Northwest Power and Conservation Council's subbasin planning efforts are examples of possible forums for this scale of planning. Other examples are the Oregon Plan for Salmon and Watersheds (see Appendix D) and ODFW's native fish conservation activities.

The City of Portland should ensure that local plans and actions are coordinated with these larger regional planning efforts.

Restoration Guidelines

Defining Restoration

There has been considerable debate on the meaning of the phrase "habitat and watershed restoration" and whether it is relevant within an urban landscape. The Society for Ecological Restoration defines ecological restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Society for Ecological Restoration Science and Policy Working Group 2002). This definition is broad enough to encompass restoration efforts within an urban setting, and is used by the City's Bureau of Parks and Recreation in its restoration efforts.

Another commonly cited definition is from the National Research Council (NRC), which defines restoration as "the return of an ecosystem to a close approximation of its condition prior to disturbance". The NRC further elaborates that it includes "functions and related physical, chemical and biological characteristics" and "is a holistic process not achieved through the isolated manipulation of individual elements" (1992, p. 17-18). According to the NRC, restoration is different from processes such as habitat creation, reclamation and rehabilitation, which partially improve one or only a few elements of ecosystem health—often to serve a particular human purpose—and do not entail a holistic restoration of ecosystem structure and function to predisturbance conditions. In this definition the NRC makes it clear that restoration is a high standard and that many projects that have been called restoration projects do not fit this definition.

The problem with the NRC definition is that it is often taken out of context and applied strictly, such that the term restoration is no longer relevant to most or all of the efforts to improve environmental conditions across the planet. In actuality it is virtually impossible to return any ecosystem to predisturbance conditions, if they are defined strictly. Even in landscapes as remote and comparatively undisturbed as the arctic, for example, polychlorinated biphenyls (PCBs) and other contaminants are present in a wide range of native biota (Wolkers and others 1998, Kucklick and others 2002); here and elsewhere, it clearly will not be possible to reestablish predisturbance characteristics for many decades, if at all. Thus if restoration according to the NRC's definition cannot reasonably be achieved even in the arctic, the definition is of little use when planning restoration actions in urban areas such as Portland.

What is often lost in the semantic debate over the term restoration is that the NRC report places as much if not more emphasis on the approach that is taken as it does on the endpoint that is ultimately reached. The NRC report includes an important quote from Berger (1990) in its definition of restoration to underscore the limits to which predisturbance characteristics can be restored:

> *It is axiomatic that no restoration can ever be perfect; it is impossible to replicate the biogeochemical and climatological sequence of events over geological time that led to the creation and placement of even one particle of soil, much less to exactly reproduce an entire ecosystem. Therefore, all restorations are exercises in approximation and in the reconstruction of naturalistic rather than natural assemblages of plants and animals with their physical environments.*

What is often lost in the debate over the term restoration is that the NRC report emphasizes approach as much as the final result.

When a word as important and broadly used as restoration is defined in a number of ways, it is important for entities to clearly define how they are using the term and to maintain consistency in their definition throughout their efforts. While some of what the City of Portland will undertake to recover fish and wildlife populations and watersheds will be consistent with the NRC definition of restoration, it is also clear that the intensity of urban development will keep the City from achieving full restoration at many locations. Thus the City will strive for "achievable restoration," using the restoration guidelines that follow. Achievable restoration means that:

- To the extent that such information is available, predisturbance conditions will be used as a guide to understanding watershed functions and shaping restoration approaches.
- Restoration efforts will focus on protecting and restoring ecological functions and processes that create and maintain watershed health, rather than on merely reintroducing structural elements (such as large wood) without restoring the processes that maintain these elements.
- The City of Portland will take a comprehensive, holistic approach that addresses all important watershed processes, rather than an approach that addresses the isolated end products of those processes (such as fish population numbers and water quality measurements).

The City of Portland is acutely aware of the intensity and severity of watershed degradation resulting from a long history of urban and industrial uses. At many locations, the intensity of urban land uses may overwhelm natural processes' ability to treat, assimilate or otherwise mitigate urban impacts; at such locations technological solutions will be needed to protect or supplement natural processes. For example, the concentration and amount of pollutants running off highways may exceed the ability of riparian vegetation (through overland flow) to treat these pollutants. In this case, technological means of treating the highway runoff (such as by routing it through a treatment swale) might be required to protect the natural processes that maintain water quality.
Within the urban environment it is likely that there will be a wide range of situations where technological solutions will be required to protect natural resources and restore watershed function.

The City's "achievable restoration" activities will draw on the comprehensive, process-based approaches and principles inherent in the NRC's rigorous definition of restoration, although the severity of past and ongoing actions may preclude full restoration of all ecosystem functions.

The City of Portland will be engaging in efforts that fall under a broad range of definitions of restoration. Some of the work will fit under the NRC's rigorous definition of restoration. Some of the work will occur in severely altered landscapes, involve the reestablishment of only basic ecosystem functions and thus be more properly classified as rehabilitation. Other efforts may fall under the NRC's definitions of reclamation, enhancement, replacement, protection and creation (National Research Council 1992). Throughout this document, where the term "restoration" is used, it is in the broader sense of "achievable restoration." Activities conducted as part of achievable restoration will draw on the same comprehensive, process-based approaches and principles inherent in the NRC's rigorous definition of restoration, even though the severity of past and ongoing actions may preclude full restoration of all ecosystem functions.

Restoration Guidelines

1. View the whole picture: Watershed restoration efforts need to be placed within the context of the entire watershed; species recovery efforts must be placed within the context of complete life cycles.

   1.1 Define watershed health holistically, by addressing the entire system. Evaluate watershed health in four dimensions: longitudinal, lateral, vertical and temporal. Define watershed health in terms of physical, chemical and biological integrity.

   1.2 Understand the role of the watershed in the landscape.

2. Characterize existing conditions and use the results to inform the entire restoration planning process.

3. When planning watershed restoration actions, prioritize and sequence them to maximize long-term success in meeting the stated objectives for the restoration.

   3.1 Begin recovery efforts by protecting and restoring existing fish and wildlife populations, functions and habitats.

   3.2 Build outward from existing populations, functions and rare or high-quality habitats. Consider the pattern and connectivity of patches as habitats and functions are built outward.

   3.3 Place priority on controlling sources of degradation before attempting to address the impacts of those sources.

   3.4 In prioritizing restoration actions, first understand how watershed processes affect watershed health. Focus initial restoration actions on the processes that create and maintain healthy watershed conditions and functions.

4. To the maximum extent practicable, use natural processes to achieve ecological functions and societal goals.

   4.1 Minimize the introduction and spread of nonnative plant and animal species, especially into relatively natural habitat areas.

   4.2 Use native species and emphasize natural habitat features and processes whenever possible in restoration activities.

The Four Restoration Guidelines

Four restoration guidelines underlie the City of Portland's efforts to achieve healthy watersheds. They attempt to translate the primary ecological; riverine, wetland and upland ecology; and salmonid principles into effective approaches for restoring watershed functions and conditions. They also describe approaches for setting the scope and scale of watershed management plans, compiling baseline information, prioritizing areas to restore and developing and sequencing specific restoration actions.

Restoration Guideline 1: View the whole picture: Watershed restoration efforts need to be placed within the context of the entire watershed; species recovery efforts must be placed within the context of complete life cycles.

In proposing restoration protocols for rivers, Stanford and others (1996) list the first as "Formalize the problem at the catchment scale" and state "the entire catchment, from headwaters to ocean, is relevant" (p. 404). The NRC (1992) considers stream and river reaches to be parts of a larger integrated riverine-riparian ecosystem that need to be understood, managed and restored as integrated parts of a single ecosystem.

The very concept of a watershed is based on the principle that the "zone of influence" for a particular stream reach extends far beyond its immediate proximity out to the furthest areas that drain to that reach. While restoration projects may not be able to address an entire watershed at once, the entire zone of influence needs to be considered and its impact on the success of any restoration activities understood. The site-specific areas typically addressed in watershed restoration projects develop within the constraints of the larger scale processes, such as climatic changes or watershed hydrology, of which they are part (Frissell and others 1986). As stated by the NRC (1992), "restoration must have a watershed perspective. Changes in any segment are communicated dynamically throughout the system. Downstream restoration can be undone by changes in the watershed, riparian zones, or upstream reaches, and the causes of failure will not be identified if these linkages are not identified and monitored" (p. 175).

An analogous systemwide focus is required for species recovery efforts. Salmonid habitat has been described as a "chain of favorable environments connected within a definite season in time and place, in such a way as to provide maximum survival" (Thompson 1959). This chain of interconnected habitats represents a temporal and spatial "pathway" through the entire ecosystem—freshwater, estuarine and marine (Independent Scientific Group 2000). For a species to complete its life cycle and survive, all components of this pathway must be functioning sufficiently to provide connectivity throughout the system. Recovery efforts that focus only on a small, site-specific portion of a species' life history chain may be unsuccessful unless the conditions and limitations beyond the specific site are understood.

The Ecosystem Diagnosis and Treatment (EDT) analytical approach—an approach used in many salmon recovery efforts across the region—essentially reflects this notion (EDT is described in more detail in Appendix H). EDT maps out the entire life history of a species and evaluates survival across the entire pathway of that life history. As stated by Lestelle and others (1996, p. 33), "ultimately environmental capacity for a population must be considered over the entire life cycle of the animal … Interest in the performance of salmon, whether we view it as a direct or indirect indicator of deliverable societal values, is long-term and most certainly includes the full life cycle."

Implications. The practical implication of this principle is not that watershed restoration activities will fail if they are not completed simultaneously over the entire watershed, but rather that any site-specific restoration activity should be understood in terms of its effects and potential for success in relation to the processes and impacts occurring over the entire watershed. Viewing the whole picture also clarifies what outcomes can realistically be expected to result from restoration actions.

Restoration Guideline 1.1: Define watershed health holistically, by addressing the entire system. Evaluate watershed health in four dimensions: longitudinal, lateral, vertical and temporal. Define watershed health in terms of physical, chemical and biological integrity.

The concept of "view the whole picture" applies not only across the landscape, but also within the dimensions of the watershed as well. Watershed health must be defined holistically, by addressing the entire system, if it is to be restored effectively. As described in Riverine, Wetland and Upland Ecology Principle 2, Ward and Stanford (1995) define four dimensions over which river processes occur: longitudinal (upstream-downstream), lateral (riverine-riparian/floodplain), vertical (riverine water column-groundwater) and temporal. The lateral dimension should also consider upland areas. For restoration activities to be designed appropriately, watershed processes, species interactions and impacts must be evaluated over these four dimensions.

Similarly, watershed health must be defined and evaluated broadly if it is to be restored effectively. Although the goal of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's water," the programs and regulations that stem from this act have focused mostly on chemical aspects of water quality, such as temperature and concentrations of metals and organic contaminants. Restoration programs must now focus more broadly on physical and biological components of watershed health, such as flow and habitat, in addition to chemical water quality (Karr and Chu 1999).

Elements of the "whole picture":

- The geographical extent of the watershed
- The range over which the species' life history is carried out
- Upstream, downstream, lateral and vertical influences throughout the watershed
- Hydrology, habitat, water quality and biological communities

The *Framework* proposes four major categories with which to evaluate watershed health:

- Hydrology
- Physical habitat
- Water quality
- Biological communities

Restoration Guideline 1.2: Understand the role of the watershed in the landscape.

"Viewing the whole picture" will require a broad, integrative framework that places rivers and streams, their habitats and their communities in a wider geographic context (Frissell and others 1986; Primary Ecological Principle 2). To fully understand the processes that shape a watershed, the watershed must be viewed and evaluated at a variety of spatial scales. The success of restoration efforts is greatly affected by processes from the broadest landscape scale (such as climate) to the basin scale (such as the Willamette River basin), watershed scale (such as the Johnson Creek watershed), reach scale and below (channel structure and dynamics, for example) (Federal Interagency Stream Restoration Working Group 1998; Primary Ecological Principle 2). No one scale is appropriate for all applications, and while a project may choose to emphasize one scale at which to conduct the most detailed and extensive analysis of restoration alternatives, it is necessary to consider processes at a range of scales for the restoration to be successful.

Stream classification systems often identify important scales to consider—and the important processes that operate over each scale—when evaluating watersheds. Stream classification systems such as that in the *Oregon Watershed Assessment Manual* (Governor's Watershed Enhancement Board 1999) classify waterways according to factors such as shape, size, gradient and dominant substrate and can guide watershed and species recovery efforts in several ways:

- By providing a framework for explicitly addressing important processes at different scales
- By identifying linkages between scales
- By describing expected watershed characteristics and functions
- By identifying the contribution of component reaches and subwatersheds to overall watershed function

Understanding the processes that affect a specific site and placing a site-specific restoration action within the context of "the whole picture" is greatly aided by stream classification systems. To be consistent with practices across the region, the City of Portland will use classification systems widely used throughout Oregon and the Northwest (Governor's Watershed Enhancement Board 1999, Montgomery and Buffington 1993, Rosgen 1994) to guide watershed and species recovery objectives and methodologies.

Restoration Guideline 2: Characterize existing conditions and use the results to inform the entire restoration planning process.

Once the "whole picture" has been defined (by understanding the range over which relevant species' life histories are carried out; the upstream, downstream, lateral and vertical influences throughout the watershed; and the hydrology, physical habitat, water quality and biological communities within a watershed), the existing conditions within the landscape of interest can be characterized. Characterization is one of the most critical initial steps in restoration planning. It is the step at which the scope and focus of restoration begin to become clear. Is the watershed or habitat degraded relative to reference conditions? What problems affect the health of a watershed or species? How do these problems vary in intensity over space and time? How do the characteristics of the watershed or habitat (gradient, climate, soils, land use, infrastructure, etc.) influence these problems, and how should these be accounted for in restoration approaches?

Comprehensively and accurately assessing existing natural and human-made conditions (such as infrastructure) throughout the course of the restoration planning process serves several purposes:

- It is useful in transforming broad and general goals into specific and measurable objectives.
- It identifies existing high-quality habitats that should be given priority for protection.

- It is critical in identifying the scope, severity and dynamics of environmental problems within a watershed. This is a prerequisite for determining the focus and priority of restoration activities.
- It defines the baseline condition against which the future progress and the success of restoration activities can be measured.

The solutions developed to restore a watershed will be appropriate and effective only if the nature and dynamics of the problems that degrade the watershed are clearly understood.

For these reasons, the characterization must be accurate, it must be comprehensive in addressing the relevant spatial scales and indicators of watershed health (to the extent possible, given existing data) and it must clearly identify key information gaps.

In characterizing existing conditions it is important to identify both the attributes of a healthy watershed and reference conditions, meaning the specific level at which each attribute is considered to be healthy or functioning (see Chapter 3 and Appendix G for descriptions of watershed attributes, indicators and target values and how they are used in the City's watershed management process).

Indicators. Following characterization and the establishment of objectives for actions to achieve watershed health, environmental indicators will be established. Developing a set of indicators is essentially a process of converting watershed goals and objectives into specific and measurable components, such as water temperature, the amount of large wood and the abundance and composition of benthic invertebrates. The challenge in identifying a comprehensive set of indicators is to develop a list that truly reflects all aspects of watershed and species health, yet that can be practically and accurately measured. It is important to view watershed health holistically, by addressing the entire system (Restoration Guideline 1.1), and to evaluate the list of indicators against a key question: If objectives for each of these indicators are achieved, are there any significant problems or processes that would be missed? Some of the indicators that can be used to evaluate existing conditions are described in Appendix G.

Reference Conditions. Once a comprehensive set of indicators has been selected, it is important to set specific target values for each indicator. However, before appropriate target values can be set, reference conditions will need to be determined. Reference conditions serve as yardsticks against which existing conditions can be compared and watershed health can be evaluated. One of the critical roles of reference conditions is to provide specific and measurable definitions of such terms as "properly functioning watershed" and "healthy populations." For each indicator, a reference condition represents a level at which the prevailing body of scientific knowledge suggests that the indicator is properly functioning.

Reference conditions may be derived from state water quality standards, habitat benchmarks such as those in the *Oregon Watershed Assessment Manual* (Governor's Watershed Enhancement Board 1999), other available criteria, evaluation of reference areas or historical conditions, or scientific studies. Reference conditions can also be determined at multiple levels, to indicate the degree to which a particular indicator is functioning. For example, NOAA Fisheries uses three levels in evaluating salmon habitat: properly functioning, at risk and not properly functioning (National Marine Fisheries Service 1996).

EDT uses five levels in evaluating salmon habitat (Lestelle and others 1996). The five levels, from 0 (meaning high survival) to 4 (meaning lethal), define salmon survival levels associated with particular conditions of each habitat attribute. Having multiple levels provides additional detail on exactly how degraded a specific indicator is and how far existing conditions are from the intended goal.

Limitations of Characterization. Characterization of existing conditions helps to identify the nature and dynamics of problems that degrade a watershed. Characterization also helps to identify existing populations and high-quality habitats that warrant protection and enhancement because they provide valuable ecological functions, or have the potential to do so in the future.

However, it is important to emphasize that characterization does not by itself identify the most critical priorities or the initial steps that must be taken to restore a watershed or recover a species. Out of the characterization will come a highly complex picture of a range of conditions and problems across the watershed. Translating the results of a characterization into objectives, indicators, target values, benchmarks and then a set of prioritized restoration actions requires additional analysis related to source identification and quantification, evaluation of alternatives and other activities.

Restoration Guideline 3: When planning watershed restoration activities, prioritize and sequence them to maximize long-term success in meeting the stated objectives for the restoration.

The complexity and pervasiveness of environmental problems in watersheds across the country, particularly in urban areas, are such that it is unlikely that all the financial resources to complete all of the actions required to achieve watershed health will be available immediately at the onset of the restoration process. This fact dictates that restoration actions be sequenced, phased or prioritized in a fashion that maximizes effectiveness in meeting watershed objectives and benchmarks. For example, if attempts are made to restore instream channel structure and habitat features before normative hydrology has been restored, excessive peak flows could destroy the restoration project. Also, artificial supplementation to recover salmon populations might not be successful unless there is habitat throughout the watershed that supports rearing, feeding, migration and spawning. Furthermore, introduction of wildlife species such as beaver may conflict with human use of the floodplain, while doing so may also help prevent channel erosion.

Given the range of problems in most watersheds, it is important to determine the most effective order in which to implement restoration actions.

A key question is "What is the most effective order in which to implement the many restoration actions required to address the broad range of problems affecting a watershed?" This approach requires a decades-long process of selecting, designing, funding and implementing a large number of restoration projects.

To determine the sequence in which projects should be implemented, several potentially conflicting criteria must be balanced:

- **Effectiveness Relative to Time and Cost.** Clearly, projects that are highly effective in meeting objectives, relative to the time or cost the projects take to implement, should be implemented early on. This is justified by both fiscal responsibility and the urgent need to reverse watershed degradation and salmon decline. Most restoration and protection efforts acknowledge this criterion, whether they refer to it as selecting the "low-hanging fruit," implementing actions with a "big bang for the buck" or identifying "early actions."

- However, for restoration to be truly comprehensive and effective, it cannot merely be a process of moving from the lowest hanging fruit to the next lowest fruit: some very difficult, costly and lengthy restoration projects will be necessary to reverse the decline of watershed health. This is particularly true within the urban landscape. Thus, additional criteria must guide the sequencing of watershed restoration projects.

- **Optimizing Riverine, Wetland, and Upland Restoration.** Restoration projects that improve riverine, wetland and upland resources can optimize resources by addressing common habitat attributes and functions and encouraging ecosystem-based approaches that benefit fish, wildlife and people. The City already has made considerable investments to conserve and restore habitat values and functions across Portland. For example, the City has acquired and manages approximately 7,000 acres of natural area parks and has established zoning mechanisms to protect or conserve more than 20,000 acres of habitat resources on public and private land. Portland also is investing in an array of programs involving revegetation and restoration projects, education and stewardship activities, and willing-seller land acquisition. Much of the future habitat work in Portland will inevitably involve restoration of degraded sites. However, opportunities to conserve existing high-quality habitats may occasionally present themselves.

  Actions to protect multiple species and/or species assemblages should be considered from an ecosystem management perspective. For example, efforts to protect habitat for bald eagles at Smith and Bybee lakes also will benefit additional terrestrial and wetland-dependent plants, fish and wildlife. Creating a conservation plan at the local level and incorporating it into a local comprehensive plan is one of the most strategic ways to protect biodiversity in urban areas (Defenders of Wildlife 2003).

- **Need.** Projects that address the most severely degraded functions or the most critical limiting factors also should be initiated early on. These projects are identified through the processes of watershed characterization and comparison to optimal values, as described earlier, and through analysis of limiting factors, as described in Appendix H. Other projects that should be considered early on are projects that protect existing healthy watersheds and functions, such as retaining urban growth boundaries and reclaiming sensitive areas via land acquisition.

  The need criterion differs from the effectiveness criterion in that these actions may be quite effective, but they are also likely to be highly complex and expensive and require a long time to implement. It is critical to initiate these projects early on, so that their eventual effectiveness is realized as soon as possible, and to commit to implementing them fully.

- **Effect on Future Projects.** Projects implemented early in the restoration process should not preclude, constrain or otherwise compromise restoration projects that will be required later in the process. While replanting riparian trees is a low-cost effort that addresses many critical watershed problems, restoration programs may not want to invest in replanting a stream reach if comprehensive watershed restoration will soon require that the reach undergo extensive bank and channel restoration to improve connections between the stream channel and the floodplain. On the other hand, if comprehensive restoration is likely to take decades, replanting may be worthwhile.

With these criteria as guidance, the order in which restoration actions should occur is determined by answering the following questions:

- "Where within the watershed should we begin restoration?" (Restoration Guidelines 3.1 and 3.2)
- "Which problems should be addressed first?"(Restoration Guideline 3.4)
- "How should these problems be addressed?" (Restoration Guidelines 3.3 and 4)

Restoration Guideline 3.1: Begin recovery efforts by protecting and restoring existing fish and wildlife populations, functions and habitats.

Species recovery planning efforts should begin by identifying existing populations of the species of interest and protecting and restoring these populations and their habitats as a first priority. The modeling tool EDT prioritizes species recovery efforts through a stepwise process of identifying existing successful life history strategies and their associated habitats (including migration corridors), improving habitats associated with these life history strategies and then improving habitat quality and connectivity to reestablish life history strategies that have been extirpated (Lestelle and others 1996).

There are several reasons why identifying existing populations can provide direction to restoration efforts:

- **As indicators of remaining ecological functions.** Surviving urban fish and wildlife populations are indicators that there are enough habitat and ecological functions being provided across a highly degraded landscape that the species in question can persist locally. If salmon traverse a "chain of favorable environments connected within a definite season in time and place" (Thompson 1959), then a surviving population is an indicator of a chain or set of chains possessing enough basic functions across the landscape that the life history strategy can be successfully completed. Stated another way, these populations are "canaries in the coal mine"; they point to a chain that is at least minimally acceptable, that can be successfully navigated and that can be built upon through restoration efforts. Addressing the key conditions that limit these existing populations is more likely to produce a viable population than attempting to reestablish populations that no longer exist. According to the NRC, "re-establishing new populations through introductions once the local populations have been lost has proved to be extremely difficult. And even if a newly introduced population is initially successful, it might not be adapted to the range of environmental conditions that have happened in the past and can be expected to occur again in the future" (National Research Council 1996, pp. 152-3).

- **As genetic resources.** Surviving urban populations also represent genetic stocks of high value to the evolutionarily significant unit, or ESU. These populations have survived in the face of extensive habitat degradation, and they may have developed adaptations that improve their survival in highly altered landscapes. "One important reason to protect local populations is that they are locally adapted to the streams that support them. In other words, evolution has made a local breeding population better able to survive and reproduce in its home stream" (National Research Council 1996, p. 152).

Restoration Guideline 3.2: Build outward from existing populations, functions and rare or high-quality habitats. Consider the pattern and connectivity of patches as habitats and functions are built outward.

Existing populations and their habitats should be expanded—and linkages to them improved—so that they can serve as "core" populations for subwatersheds without populations. Populations of salmonids and many other fish and wildlife species are best viewed as metapopulations (National Research Council 1996), meaning a collection of nearby populations that interact and can exchange individuals, and many believe that salmonids exhibit a core-satellite metapopulation structure (see the salmonid ecology principles section and citations contained therein). In such a structure, core populations serve as important sources of colonists that reestablish satellite populations in nearby habitats where populations have been extirpated. These populations already have a high probability of being adapted to conditions in nearby habitats (National Research Council 1996).

"Building outward from existing populations" means the following:

- Improving and expanding habitats in which populations currently exist.
- Improving connectivity to nearby favorable habitats to increase the chances of the existing populations straying into these habitats and establishing satellite populations. (This is consistent with the "maximize passage efficiency to allow recovery of metapopulations" restoration protocol in Stanford and others [1996]).

In the long run it is easier to protect existing functioning habitats than it is to create new ones.

Just as restoring existing populations has a greater probability of success than attempting to reintroduce populations where none currently exist (Restoration Guideline 3.1), protecting existing high-quality habitats is more likely to meet with success than restoring habitats that are in a degraded condition. This essentially implements the first portion of the concept "protect the best, restore the rest." Species recovery efforts should acknowledge that remaining habitats of high ecological value provide critical, irreplaceable functions for species of concern. These critical habitats will be determined by the life histories of the species of concern. For salmonids, for example, habitats of high ecological value might include off-channel habitats, floodplains, islands, springs and confluences; for priority wildlife species such as riparian- or upland-dependent birds, high-quality habitats might include those with the critical combination of food, cover and water. These valuable areas should be given priority for protection, restoration, improved access and expansion. Frissell and others (1986) state that protection of existing functioning habitats is the most urgent and cost-effective habitat conservation measure.

However, it is critical to emphasize that, as a priority, "protect the best" is incomplete without "restoring the rest." Even if all currently existing habitats were protected from any further degradation, the populations of salmon and many other fish and wildlife species would still remain below historical levels, in part because of a lack of high-quality habitat. Local and regional efforts to comply with Statewide Planning Goal 5 for protection of fish and wildlife habitats focus on "protect the best" but not on "restoring the rest." Restoring conditions and habitats must go hand in hand with protection efforts. For example, while protection of existing high-quality habitats is a necessary and important step, by itself it is insufficient to restore salmon populations because the amount of remaining habitat is inadequate to maintain viable salmonid populations. If the intention of restoration programs is to recover populations rather than merely prevent additional harm or further decline in populations, the restoration programs must improve the functionality of existing habitats or create additional habitats beyond those that currently exist, or do both. Another issue that is central to assisting with the recovery of listed salmonids is that the vast majority of Portland's highest quality (and fully protected) habitats, including Forest Park and Oaks Bottom, are inaccessible to anadromous fish species.

Given the difficulty of restoring habitat to the quality and functionality of naturally created habitat, one of the most effective ways of increasing habitat functions throughout the watershed is to improve the connectivity of existing habitats by reducing bottlenecks and blockages among them. Bottlenecks and blockages occur in the form of physical barriers, excessive or inadequate flow, water quality barriers or other forms of habitat degradation. The presence of degraded habitat between migratory routes and high-quality habitats precludes or limits access to high-quality habitats; it also reduces or eliminates the valuable functions such habitats could otherwise provide to migratory species. Consistent with the discussion of the riverine, wetland, upland and salmonid ecology principles, improving the connectivity of existing functioning habitats will strengthen existing populations and metapopulation structure (Stanford and others 1996) and promote expansion into favorable but unoccupied habitats.

The distribution of patches of habitat is an important component in wildlife habitat relationships. The amount of habitat, variation in patch size and isolation of certain patches influence both species viability and diversity, with implications for management actions.

Large habitat patches are more likely to sustain ecological processes and historical disturbance regimes than small patches are. In addition, large patches support more viable and diverse populations of native plants and animals, including species such as brown creeper and Douglas' squirrel that are adapted to interior habitats. Small patches typically support fewer species and individuals than do large patches of the same habitat type, and those species are more likely to be edge-adapted species, including predators such as coyote. However, small patches may also contain rare or unique habitat types or species or act as "stepping stones" between otherwise isolated patches of habitat. When considering management actions, it will be important to evaluate which wildlife species, at which life stages, would benefit from the restoration of large and small patches. Also, it is crucial that upland habitats have some degree of connectivity to other upland habitat patches and to aquatic and riparian habitats. Strategically connecting patches of various sizes could help wildlife species disperse across the landscape, access less developed landscapes and meet those biological needs not satisfied by riparian and aquatic habitats alone.

Restoration Guideline 3.3: Place priority on controlling sources of degradation before attempting to address the impacts of those sources.

Source Identification. Source identification is the step at which the processes degrading a watershed are identified and quantified and is therefore critical for developing and prioritizing solutions. Unfortunately, in the past, both in Portland and elsewhere, many restoration plans attempted to go directly from identifying problems to identifying solutions. For example, if a watershed exceeded temperature standards, oftentimes trees were planted in areas where riparian vegetation was lacking; if there was a lack of habitat supporting spawning, restoration projects were implemented that re-created suitable substrate and instream conditions to support spawning. It is possible with such an approach to identify many actions that may improve degraded conditions in the watershed.

However, the danger of such an approach is that, if efforts are not directed toward understanding the processes that produce the problems, the restoration actions might address only the symptoms of the problems, without solving the problems themselves. For example, knowing that a particular stream reach has insufficient gravels to support spawning is different from knowing whether gravels are limiting as a result of (1) excessive sedimentation, (2) an upstream barrier that impedes gravel transport and "starves" the reach of gravel, or (3) changes in hydrology that alter the transportation and deposition dynamics of the reach. Similarly, knowing that DDT is present in stream sediments at levels that impair ecosystem health is different from knowing whether the DDT (1) originates from past uses and is predominantly stored within aquatic sediments, (2) is attached to upland soils throughout the watershed and is introduced into the aquatic environment through erosion, or (3) is still being used by watershed residents and so has active sources that need to be addressed.[5] In each of these examples there are three possible solutions to what appears to be the same environmental problem. Unless the relative contributions of the different sources are understood, an effective solution cannot be developed.

To the extent possible, protection and restoration programs should place high priority on identifying and quantifying sources or causes of degradation before attempting to address the impacts of those sources within the environment. Money and effort spent on carefully and quantitatively evaluating sources offer multiple benefits:

- Knowledge of which sources it is most important to control
- An understanding of the dynamics of those sources and how best to control them
- An ability to predict quantitatively the benefits that will accrue from controlling each source, taking into account the cumulative impacts of multiple sources
- An ability to avoid creating an "attractive nuisance" that could draw fish or wildlife into habitat where they either cannot be sustained or can be harmed

Insufficient efforts directed toward source identification may result in misdirection of source control efforts. Without a sufficient understanding of source dynamics, the most significant sources may not be addressed and source control policies, programs and technology may be misapplied.

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[5] All three of these sources have been shown to be active in the Columbia Slough, for example (City of Portland Bureau of Environmental Services and Parametrix 1997).

Source Control. Once sources of degradation have been identified and quantified, restoration plans should place priority on controlling sources before attempting to address the impacts of those sources within the watershed. Decades of water quality protection efforts have made it clear that source control is by far the cheapest and most effective path to water quality. The general rule of thumb is that in relative terms it costs $1 to control a pollutant at its source, $10 to treat it at the end of the pipe and $100 to clean it up once it enters the environment. In addition, each step is less effective than the previous one. This is particularly true for certain organic contaminants, which often break down extremely slowly over time and whose chemical properties tend to resist dilution and favor incorporation into sediments and the food chain. Thus the general principle is that restoration plans must control sources of degradation as close to their sources as possible.

In relative terms, it costs $1 to control a pollutant at its source, $10 to treat it at the end of the pipe and $100 to clean it up once it enters the environment.

While the importance of source identification and control has been recognized in connection with water quality programs, its importance and applicability have been less widely acknowledged in connection with protection and restoration efforts that address hydrology, habitat and biological communities. The same principle of addressing causes rather than symptoms applies equally well to these areas. Attempts to restore degraded habitat are never as successful as protecting habitat from destruction or degradation in the first place. Similarly, aggressive efforts to prevent the introduction of exotic species will always be more effective and cheaper than trying to eradicate an invasive species that has already established itself within the ecosystem.

Lack of source control prior to restoration is likely to result in failure of the restoration project. For example, a stream channel restoration that does not address the altered hydrology that causes channel degradation will probably be destroyed by excessive peak flows. Likewise, if contaminated sediments are cleaned up but the source of pollution is not controlled, the sediments will be recontaminated.

It is particularly important to control sources of toxic pollutants before they are released into the environment and enter the food web. Many of the persistent, bioaccumulative pollutants common in urban settings degrade very slowly (if at all) through natural processes, and have adverse impacts on biological populations. Urban wildlife are exposed to a host of chemicals—pesticides, PCBs, heavy metals, and other contaminants—that even at sublethal concentrations can affect survival. In birds, for example, nonlethal and indirect exposure to pesticides can lead to increased susceptibility to predation and changes in avian egg incubation behavior. Repeated pesticide exposure also adversely affects nutrition, reproduction and growth of animals such as gamebirds and waterfowl (Bennett 1992). In addition, being exposed to toxic chemicals can increase terrestrial species' stress, predispose organisms to disease, delay development and disrupt physiological processes such as reproduction.

Although fish and other aquatic species are particularly susceptible to the direct effects of water-borne toxins, terrestrial species that feed on aquatic species also can be affected by toxins through bioaccumulation. This is the case with piscivorous birds such as bald eagles and osprey. Bald eagle eggs from nests in the Columbia Slough area and osprey eggs from nests along the lower Columbia River have been found to contain unsafe levels of DDE (a metabolite of DDT), PCBs, dioxins and other toxins that may affect their productivity.

Restoration actions that would help wildlife avoid exposure to toxic chemicals, either directly or through bioaccumulation, would include those actions that reduce sediment accumulations, or discharges and nonpoint source runoff that may be contaminated.

Restoration Guideline 3.4: **In prioritizing restoration actions, first understand how watershed processes affect watershed health. Focus initial restoration actions on the processes that create and maintain healthy watershed conditions and functions.**

Restoration actions should be sequenced for maximum effectiveness, considering the importance of hydrology, habitat creation and maintenance, and water quality, which are key, interlinked processes for restoring watershed health.

Hydrology. Regardless of whether restoration is applied to large rivers, small streams wetlands or uplands, hydrology is one of the most basic and critical forces shaping and shaped by the structure, dynamics and function of riverine and wetland ecosystems (see Riverine Ecology Principle 3). Flow dynamics affect nearly every aspect of ecosystem functioning, including habitat formation and maintenance, the flow of energy and materials, temperature, the fate and transport of contaminants and the composition of biological communities. Stanford and others (1996) emphasize the primary importance of flow in the health of large rivers and regard it as one of the most pervasive impacts on large rivers across the globe. Poff and others (1997) consider flow a "master variable" that regulates the ecological integrity of river ecosystems. In smaller systems, many researchers have documented the strong association of stream health with the amount of watershed imperviousness (Booth 1991, Schueler 1994, May and others 1997), an association that is due partly to the effect of impervious surfaces on watershed hydrology, specifically changes to overland flow and baseflow.

Regardless of whether restoration is applied to large rivers or small streams, hydrology is one of the most basic and critical forces shaping the structure, dynamics, and function of riverine ecosystems.

Because of the critical importance of flow in ecosystem structure and function, restoration of other watershed components may be unsuccessful or of limited benefit unless significant elements of normative flow are restored (Beschta 1996, Kauffman and others 1997). Restoration of physical habitat may be destroyed by excessive peak flows or rendered inaccessible to fish by inadequate flows. Restoration of normative flow will have fundamental impacts on elevated temperatures and on the fate and transport of contaminants. Attempts to restore healthy aquatic communities must restore the range and timing of flow to which the species have adapted over evolutionary time.

Even within subwatersheds where existing conditions and constraints preclude the ability to fully restore normative flow, it is important to evaluate the flow regime that ultimately will be attained through the restoration actions planned for that subwatershed. The physical form of the channel; the extent, proximity and composition of riparian and upland vegetation; water quality dynamics; and the composition of instream communities—all will be strongly influenced by the hydrologic regime that the restoration actions ultimately provide. Until a reasonably clear picture of that hydrologic regime and the projects needed to produce it emerges, it will be difficult to know the types of habitat that can be restored in different locations within the watershed.

Restoring water quality also will require an understanding of the flow regime that will be attained through restoration. The assimilative capacity of a stream (meaning the amount of pollution, heat, nutrients and sediments the stream can accommodate before violating the Clean Water Act) is key in planning water quality restoration, and flow regime is a critical component in estimating assimilative capacity. Knowing assimilative capacity and flow regime in turn provide a clearer picture of the conditions that are likely to exist throughout the watershed, and the types of plant and animal communities that will survive in these conditions.

For all of these reasons, some of the first actions to occur in restoring urban watersheds should be (1) evaluation and planning of the restoration actions needed to restore normative flows, and (2) an analysis of the extent to which normative flows can be restored. It is likely that restoring normative flows will require actions throughout the watershed (for example, removal or reduction of impervious surfaces). The extent to which normative flow is reestablished will greatly affect the degree of success in restoring other elements of urban watersheds.

Physical Habitat. Frissell and others (1986) emphasize the importance of physical habitat in the structure and function of riverine ecosystems. When combined with hydrologic restoration, the restoration of physical habitat may address other forms of watershed degradation. For example, stream temperatures can improve dramatically once channel structure, riparian areas and normative hydrology are restored. The importance of wetland and riparian vegetation in nutrient cycling, runoff filtration and determining the balance between autochthonous (instream) and allocthonous (out of stream) primary production makes habitat restoration a key strategy in addressing stream eutrophication. Restoring physical habitat to conditions to which native species have adapted over evolutionary time is key in reducing the dominance of invasive species and recovering healthy biological communities.

Aquatic habitats are created by the interaction of flow, wood and substrata (gravel, sediments, bedrock, etc.) (Naiman and others 1992, Washington Forest Practices Board 1995). Restoring normative flow, restoring and improving connection to riparian and floodplain areas and restoring normative sediment supply processes are some of the key elements required to restore habitat. Given the importance of the floodplain in flow attenuation and storage, habitat processes, provision of refugia and water quality (Stanford and others 1996; riverine ecology principles), restoring river connection to floodplains is a critical element of habitat restoration in floodplain systems. Similarly, understanding how upland habitats are created is important in restoring watershed health.

The following is the City of Portland’s prioritization scheme for habitat protection and restoration, adapted from the NRC’s habitat management options (National Research Council 1996, pp. 206-210):

1. **The highest quality riverine, wetland and upland habitats should be protected. Fish and wildlife access to these habitats should be evaluated and, wherever possible, restored or improved.** Opportunities for protection and even expansion of these

habitats (such as by improving species' access to adjacent high-quality habitats or restoring nearby habitats) should be investigated. Within Portland, examples of high-quality habitat include Smith and Bybee lakes, Forest Park and portions of Tryon Creek. These areas currently are protected, but aquatic species' access to them is compromised or precluded by culverts or water control structures. Similarly, the City's Environmental Overlay Zones provide some protection to a number of streamside habitats and should be expanded, where warranted. In addition, Metro's Goal 5 Regionally Significant Areas Inventory should be evaluated and expanded within the City of Portland, where appropriate, to address areas of local importance.

2. **Intermediate-quality habitats should be conserved and evaluated for restoration.** Intermediate-quality habitats have been degraded by human activities but have the potential to recover characteristics that would make them functionally equivalent to high-quality habitats. Riverine, wetland and upland habitats in this category that are contiguous with or along migratory routes to high-quality habitats should be given additional priority. Crystal Springs is an example of such a habitat. Located in the lower Johnson Creek watershed, close to the Willamette River, Crystal Springs is used by local fish populations and as off-channel habitat by salmon migrating along the Willamette mainstem. Restoration projects at Crystal Springs could greatly improve its ecological functions because Crystal Springs has large inputs of groundwater and its upper portion is situated among parks, a golf course and a college campus, which reduces constraints to riparian and channel restoration.

3. **The lowest quality habitats should be evaluated for their potential to create "bottlenecks" and to fragment habitat.** Areas that are highly degraded (such as through toxic contamination, habitat destruction, high temperatures or excessive or inadequate flows) may impede or prevent species from reaching higher quality habitats, increase mortality or decrease individuals' fitness as they pass through these degraded areas. Degraded areas that are near or between high-quality areas, or along migratory routes to high-quality areas, should be given additional priority. In a sense, the Willamette River through downtown Portland represents such a habitat. Habitat degradation through this reach may affect fish populations from throughout the Willamette River basin that must pass through the lower Willamette to reach spawning and rearing habitats above Portland.

Water Quality. As discussed previously, restoration of flow and habitat will restore many of the processes that maintain water quality. Attention should then be focused on those components of water quality that are not addressed by reestablishing normative flow and restoring riparian and instream habitats, such as toxic contamination.

The extensive focus of past environmental programs on water quality has provided some valuable lessons that can be generalized to broader forms of restoration. The first of these is that the quality of instream waters is intimately connected to the conditions and activities of the surrounding uplands. Upland areas are an integral and inseparable component of the watershed, and conditions and activities occurring in the uplands are transmitted—often via water quantity and quality impacts—to the streams into which they drain. This concept is captured under the "lateral" dimension in the riverine ecology principles and under Restoration Guideline 1.1. The second lesson learned is that source control, protection and prevention are by far the cheapest and most effective forms of restoration. This is described further in Restoration Guideline 3.3.

Biological Communities. Decisions regarding restoration that involve direct manipulation of biological communities (invasive species control, hatchery introductions, etc.) should evaluate the degree to which degraded flow, habitat and water quality conditions can compromise the effectiveness of these measures. As stated in Primary Ecological Principle 4, "the abundance, productivity and diversity of organisms are integrally linked to the characteristics of their ecosystems." Attempts to reintroduce native species or reduce the dominance of introduced species may fail if the habitat conditions to which native species have adapted are not reestablished (National Research Council 1996). The alteration of these habitat conditions may in fact be the primary factor that gives invasive species competitive advantages over native species (Reeves and others 1987). Thus the highest priority in restoring biological communities should be to address the flow, habitat and water quality conditions that led to the decline of these communities.

Restoration Guideline 3 and its subprinciples provide guidance on how to sequence the evaluation and implementation of restoration actions and how to determine where in the watershed these actions should be implemented first. Restoration Guidelines 3.3 and 4 provide guidance on the restoration actions themselves (that is, the nature and type of restoration actions that should be emphasized in developing comprehensive watershed management plans).

Restoration Guideline 4: **To the maximum extent practicable, use natural processes to achieve ecological functions and societal goals.** Watershed and species recovery efforts should focus on restoring rather than replacing natural processes to the maximum extent possible (Independent Scientific Group 2000). Stanford and others (1996) emphasize the importance of natural river processes in habitat formation and maintenance under the restoration protocol "let the river do the work." This idea is captured throughout ecological literature in the concept of passive or "self-design" restoration, which is the process of halting activities and removing structures that are causing degradation or preventing recovery and allowing natural processes to restore ecosystem functioning. Beschta and Kauffman (2000) and Kauffman and others (1997) state that passive restoration is the logical and necessary first step in any restoration program.

Restoration Guideline 4 is consistent with and builds upon themes expressed in the other restoration principles:

- Simply reducing or eliminating sources of degradation may be the most important and effective step in restoring degraded watersheds (Restoration Guideline 3.3).
- Restoring existing populations has a greater probability of success than attempting to reintroduce populations where none currently exist (Restoration Guideline 3.1).
- Protecting existing high-quality habitats has a greater probability of success than restoring habitats that are already in a degraded condition (Restoration Guideline 3.2).

Essentially, Restoration Guideline 4 states that natural processes are generally far more effective and cheaper than the technological processes designed to replace them. While some restoration efforts will involve using engineered solutions to allow natural processes to reestablish themselves, wherever possible restoration plans should make use of natural processes to perform ecological functions, rather than rely heavily on technological options—many of which do not have a proven track record of success.

There may be a strong bias against approaches that promote natural processes within the urban landscape, for two main reasons:

- The intensity and pervasiveness of land uses appear to be inconsistent with the space required to allow natural processes to occur.
- Natural processes are inherently dynamic and unpredictable.

However, many of the most innovative emerging restoration approaches—approaches that are showing the greatest potential in terms of effectiveness and cost—are those that embrace the concept of using natural processes to achieve ecological and societal functions.

Example: Flood Control vs. Flood Management. For example, more than 70 years of traditional flood control approaches in Johnson Creek have failed to control floods and, in the meantime, have been detrimental to the ecological health of the watershed (City of Portland Bureau of Environmental Services 2001). As an alternative, the City of Portland has attracted national attention and gained the recognition and support of the Federal Emergency Management Agency (FEMA) by focusing on innovative approaches of flood "management" that have included the following:

- Purchasing and demolishing willing-seller properties within the floodplain
- Reconnecting floodplains so as to reestablish flood storage throughout the watershed
- Re-creating off-channel habitats
- Removing fill and structures within the floodplain

Example: Stormwater Management. Nationwide, the newest and most promising trend in stormwater management is trying to minimize the reliance on traditional conveyance, pond technologies and end-of-pipe systems. These are being replaced by approaches that focus on the following:

- Reducing building and road footprints to reduce the amount of impervious surfaces
- Using permeable surfaces where footprints cannot be avoided
- Using small, decentralized bioretention areas that infiltrate, store and transpire precipitation locally throughout the watershed (Hinman 2001)

These newer approaches make far greater use of localized infiltration and the associated natural process that provide flow and water quality benefits. Initial research indicates that these approaches are more effective than traditional stormwater management approaches with comparable costs, even within highly constrained urban areas (Liptan and Kinsella-Brown 1996). Decentralized bioretention areas also have the potential to play a significant role in flood management; this indicates that effective flood management is not restricted to actions only in the floodplain.

The Role of Technological Solutions. Clearly, the intensity and pervasiveness of urban land uses may overwhelm the ability of natural processes to mitigate all urban impacts. For example, the concentration and amount of pollutants running off highways may exceed the ability of riparian vegetation (through overland flow) to treat these contaminants. In such cases technological solutions will be needed to protect urban natural resources and restore watershed function.

That said, the point of Restoration Guideline 4 is twofold:

- Wherever possible, restoration efforts should include solutions that make use of natural processes within the urban environment.
- Where excessive constraints simply preclude the use of natural processes, technological solutions should be designed to mimic natural processes to the maximum extent possible, with an understanding of the natural processes they seek to replace being reflected in the design. In addition, solutions should be designed to place as few constraints as possible on natural processes.

Restoration Guideline 4.1: Minimize the introduction and spread of nonnative plant and animal species, especially into relatively natural habitat areas. Numerous fish, wildlife, and plant species have been introduced into Portland's watersheds, either intentionally or by accident. These species alter food web dynamics, transmit diseases and parasites, and may outcompete native species, especially if the introduced species have no natural enemies in their new habitat. Introduced species are particularly adept at capitalizing on altered or degraded habitats such as those in urban areas like Portland. Unfortunately, once introduced species become established they are difficult to control or eliminate. They can lead to permanent alterations of the biological integrity of the ecosystem, and their presence, combined with habitat alteration, can deplete or replace populations of native species. In fact, in urban environments, competition from nonnative plant and animal species is second only to habitat loss as a cause of native species decline (Defenders of Wildlife 2003). According to Suter (1993), some of the most severe effects of human activities on the world's biological communities have resulted from the introduction of exotic organisms.

For these reasons, restoration actions should minimize the introduction or spread of nonnative species, to prevent additional disruption of existing ecosystem processes and functions. This is especially important in relatively natural or undisturbed habitat areas that are already supporting assemblages of native plant and animal species (species that, as described in Primary Ecological Principle 5, themselves help develop and maintain healthy ecological conditions).

Restoration Guideline 4.2: Use native species and emphasize natural habitat features and processes whenever possible in restoration activities. Ecosystem management requires an emphasis on native species. Not only are native species best adapted to the local climate and ecological conditions, but they also play an important role in developing and maintaining those conditions. As described in Primary Ecological Principle 5, species provide ecological functions such as cycling energy and nutrients, structuring habitat and regulating the composition of natural communities through interactions with competitors, predators and prey. Although introduced plant and animal species in urban areas such as Portland may provide habitat values and ecological functions, these values and functions often are less than those of a fully functioning native ecosystem. The configurations of habitats and species resulting from the introduction of nonnatives represent a different, less desirable ecosystem than a natural one that supports a full complement of native species. At worst, introduced species disrupt key ecosystem processes and can lead directly to the decline of native species, as described in Restoration Guideline 4.1, and further ecosystem degradation. For these reasons, restoration actions should use native species whenever possible.

CHAPTER 3

Managing Portland's Watersheds

Overview

The City of Portland is committed to achieving and maintaining healthy urban watersheds, as expressed through the four watershed health goals presented in Chapter 1.[1] This does not mean replicating historical conditions. The City defines a healthy urban watershed as one where hydrologic, water quality and habitat conditions are suitable to protect human health, maintain viable ecological functions and processes, and support self-sustaining populations of native fish and wildlife species whose ranges include the Portland area.

This chapter describes how the scientific principles and restoration guidelines in Chapter 2 will be applied to achieve the watershed health goals in Chapter 1. The intent is to provide a systematic, consistent way of making decisions about management of the City's watersheds, using principles of adaptive management.

This chapter of the *Framework* describes two major aspects of watershed management:

- The general steps involved in developing watershed management plans and selecting, implementing and monitoring actions taken to achieve watershed health goals
- Other things the City will do to ensure that its actions are as consistent as possible with the scientific principles and watershed health goals and objectives

Watershed Plans. The process of developing and implementing watershed management plans is described in a stepwise manner. However, in actual application the process is iterative and ongoing. It will involve repeatedly revisiting certain steps and stages to refine assumptions, update information and adjust the watershed management plans accordingly. Thus the watershed management plans and the related documents that will result from this process should not necessarily be thought of as final and static; rather, they will be revised as needed, in whole or in part, much the way pages in a loose-leaf binder are removed and replaced as needed.[2]

The process of developing and implementing watershed management plans is iterative and ongoing. It will involve repeatedly revisiting certain steps to refine assumptions, update information and adjust the watershed management plans accordingly.

This chapter presents a structured and consistent approach to the development and implementation of watershed management plans. However, it will not be possible to follow the process exactly as presented for various reasons, such as the existence of data gaps and the need for flexibility

[1] The City's Natural Resources Team coordinates watershed management within the City; this involves the integrated efforts of a wide variety of programs and bureaus.

[2] This will necessitate careful tracking and documentation of information and decisions, using systems such as an environmental management system (EMS). An EMS is a continual cycle of planning, implementing, reviewing and improving the processes and actions that an organization undertakes to meet its environmental goals.

to take advantage of funding opportunities. That said, the City intends to follow the process as closely as possible, applying the scientific principles, restoration guidelines and analytical tools as described. As steps of the process are revisited and new information is incorporated, it will become easier to follow the process. Revisions to the watershed management plans and related documents that are made over time will reflect increased scientific understanding of watersheds and restoration techniques.

The City of Portland's watershed management process, which leads to the development and implementation of watershed management plans, has four stages:

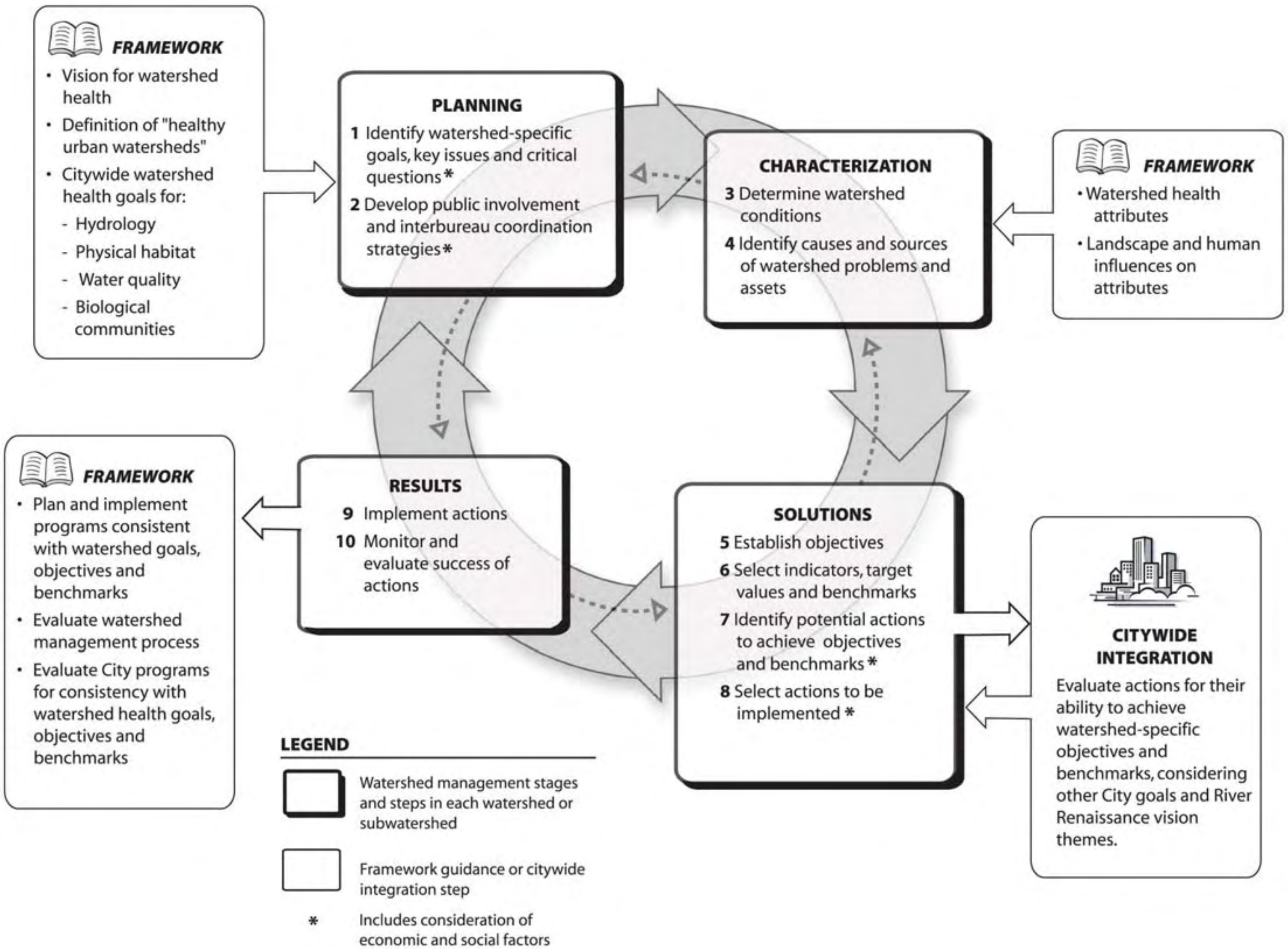
- **Planning.** At this first stage, watershed-specific goals are established. Key issues and critical questions are identified—including those related to economic and social concerns—and scopes of work are developed for the activities needed to create a work plan for each watershed. During this stage, strategies are developed to ensure stakeholder and public involvement, as well as interbureau coordination.
- **Characterization.** At the second stage, historical, current and near-term future[3] conditions of each watershed are assessed, documented and described. Problems[4] that may warrant potential actions—and their causes and sources—are identified and prioritized. Similarly, watershed processes or features that are currently functioning well and that may be key to sustaining important watershed functions (referred to as watershed assets) are also identified and prioritized.
- **Solutions.** In this stage, watershed-specific objectives are developed for protection, restoration or enhancement of important watershed conditions identified during characterization. Appropriate environmental indicators and targets, along with benchmarks, are selected for measuring progress in achieving the objectives. Potential actions are identified, evaluated and prioritized, and a preferred set of properly sequenced actions is selected. Final selection of actions to be implemented is made based on several decision-making factors, including consideration of other City goals.
- **Results.** The selected actions are implemented, and their success is monitored and evaluated. The actions may be adjusted as their effectiveness becomes clearer, as understanding of watershed functions increases and as techniques for watershed management, protection and restoration improve over time.

Figure 3-1 shows the individual steps within these four stages. The figure also shows at what points integration occurs with other citywide goals and actions. The figure conveys the continuous nature of the watershed management process: effective watershed management involves ongoing adaptive management and feedback to ensure that implemented actions have the desired outcome and that watershed goals are achieved. As knowledge and insights are gained, the watershed-specific objectives, indicators, targets and benchmarks may be modified.

[3] Near-term future conditions are those that are certain to occur over the next several years.

[4] "Problems" refer to watershed conditions or features that are contributing to impairment of watershed and river health.

FIGURE 3-1
Stages and Steps in the Watershed Management Process



Beyond Watershed Plans. Not all decisions leading to actions to protect or improve watershed health will emerge from the watershed management plans that are developed. For example, new projects will be proposed as a result of other City efforts, such as road building and urban renewal. However, the scientific principles, watershed steps and analytical tools described in this *Framework* can be applied to virtually any project to reduce its potentially negative impacts on watershed conditions, or even to improve watershed conditions.

In addition, some new City of Portland plans and documents, such as total maximum daily load (TMDL) implementation plans, will emerge and will reflect decisions made during the watershed management process. It is likely that other, existing plans, such as urban renewal and transportation plans, will be modified to be aligned with these decisions.

Lastly, day-to-day City operations will inevitably be influenced by the watershed management approach. The City already is striving to alter its practices to be more environmentally responsible. Over time, the watershed concepts and principles in this *Framework* will also be integrated into the everyday activities of City government.

Scope. The City of Portland is applying the scientific principles and watershed management steps in each of the following watersheds[5] within the City's jurisdiction[6]:

- Lower Willamette River[7]
- Columbia Slough
- Johnson Creek
- Tryon Creek
- Fanno Creek

The City also will apply those principles in parts of the Columbia River that are within its jurisdiction.

Most of the watersheds in the Portland area cross jurisdictional boundaries. Therefore, throughout all stages of the watershed management process, it is important to understand the regional context of Portland's watersheds and the activities of other entities. This will be accomplished through ongoing coordination with these other entities on watershed management goals and objectives, data collection and analysis, and planning and implementation of actions aimed at watershed protection and enhancement. Regional coordination activities are addressed in more detail in Appendix D.

The Willamette and Columbia River basins extend far beyond Portland. The City's practical focus on these large rivers and their watersheds will be those parts that are within the City's jurisdiction. However, watershed management will incorporate a basinwide understanding of the condition of natural resources, to more fully develop the needed context for assessing conditions and potential actions for natural resources at a local level.

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[5] Although each of these is referred to as a "watershed," they can also be thought of as subwatersheds within the larger lower Willamette River watershed.

[6] The Bull Run watershed, which supplies water for the City of Portland, is not included because it is part of a separate but similar planning process being conducted by the City's Water Bureau.

[7] The City's jurisdiction in the Willamette watershed includes (1) the mainstem river from approximately the Sellwood Bridge to the confluence with the Columbia River, and (2) several subwatersheds that drain to the river within Portland (such as central eastside areas and Balch Creek and other Forest Park tributaries in the West Hills).

Developing and Implementing Watershed Management Plans

The following steps are being applied citywide, and within each of the City's individual watersheds, in order to develop and implement watershed management plans aimed at achieving the citywide watershed health goals.

Watershed management plans and sets of actions will be developed, tailored to the specific characteristics and issues in each watershed or subwatershed. Problems common to multiple watersheds may lead to citywide solutions.

Planning: Identifying Goals, Issues and Coordination Strategies

The planning phase sets the stage for all other steps in the watershed process. During this phase, watershed-specific goals are developed, key issues and coordination strategies are identified and a stakeholder involvement strategy is developed. This clarifies the basic scope of the watershed management process for the stages and steps that follow.

Step 1: Identify Watershed-Specific Goals, Key Issues and Critical Questions

Watershed-Specific Goals. Step 1 involves establishing watershed-specific goals for each of the watersheds. These will be the same as the four broad, citywide goals proposed in Chapter 1 relating to hydrology, physical habitat, water quality and biological communities. However, additional watershed-specific goals may be developed to address other existing City and regional goals, plans and policies that relate to watershed management, such as public health and safety and public participation.

Key Issues and Critical Questions. Once the watershed-specific goals are defined, key issues and critical questions will be identified to provide guidance and focus during the characterization phase (Steps 3 and 4). Many key issues and critical questions to be addressed in watershed management will fall into the same environmental categories used to set the watershed-specific goals—that is, hydrology, physical habitat, water quality and biological communities. For example, regarding hydrology, critical questions could include the following:

- What factors alter stream flow and volume?
- Is flooding a problem? Where does flooding occur, and what is its frequency?
- What influence does upland management have on stream and stormwater conveyance?
- What critical flow conditions occur that affect channel conditions and physical habitat?
- What types of solutions are available to restore more normative hydrology?

Critical questions related to water quality could include the following:

- What are the major pollutants and their sources?
- What stream reaches have high water quality, and what reaches are degraded?
- What effects do stormwater outfalls have on water quality, and where do they occur?
- What impact do unsewered areas have on water quality, and where do they occur?
- What are the moderating effects of groundwater discharge on stream temperatures?

With regard to habitat and biological communities, critical questions could include the following:

- What are the key ecological functions and habitat attributes in the watershed?
- What are the key species in the watershed? What are their life stages, and when and where do they use habitats in the watershed?
- What habitat features or conditions are currently limiting biological communities in the watershed?
- What invasive or nonnative plant and animal species are in the watershed, and what is their status? (For example, are they spreading rapidly? Are they under control? Are they threatening specific native species of concern?)

Issues and questions related to economic and social factors, public health and safety, public involvement and coordination with City policies also are identified in Step 1.

These are just a few examples. The list of key issues and critical questions used to guide characterization will also include questions and issues regarding economic and social factors, public health and safety, public involvement, monitoring, and coordination and consistency with City policies, regulations and other plans. All of these can be related to watershed health.

Step 2: Develop Stakeholder, Public Involvement and Interbureau Communication and Coordination Strategies

Step 2 involves the following:

- Developing a public involvement strategy that outlines communication and consensus-building activities with stakeholders and the public
- Determining the roles and responsibilities of City of Portland staff and teams
- Identifying how the City will participate in watershed-related efforts in other jurisdictions and involve others entities in the City's processes, when appropriate
- Developing work plans

Because success relies in part on public understanding and support, a public involvement and communication strategy is one of the most important aspects of watershed management.

Stakeholder and Public Involvement. Involvement of stakeholders and the public is critical during all stages and steps of the watershed management process. Because the watershed management process described in this *Framework* is ongoing, and because success relies in part on public understanding of what the City is trying to achieve and how it intends to achieve it, developing a clear communication and public involvement strategy is one of the most important aspects of watershed management. An effective public process will provide opportunities for people to learn, engage, give their input on economic and social factors that affect watershed health, and help shape decisions both in individual watersheds and across watersheds. The process should offer diverse options for participation, from general information open houses to targeted interactions with key individuals and organizations.

For the purposes of this *Framework*, stakeholders and the public are defined broadly and include local and regional businesses, neighborhood groups, environmental and other organizations, other jurisdictions, governmental agencies, key stakeholders and citizens who may not be affiliated with any organized or readily identifiable group.

Identifying Roles and Responsibilities. One of the key aspects of the *Framework's* watershed management process is that it integrates the efforts of multiple City bureaus and programs to achieve watershed health goals. Responsibility for developing watershed management plans currently resides primarily in the Bureau of Environmental Services but also involves other programs within the bureau, such as the Science, Fish and Wildlife Division's Endangered Species Act (ESA) Program and Engineering Services, as well as other City bureaus, such as the Planning Bureau. Roles and responsibilities for implementation and monitoring will be determined after the selection of actions and may fall to a variety of bureaus, such as Transportation, Parks and Development Services.

Working with Other Jurisdictions. Another aspect of watershed management is to identify how the City will participate in similar watershed-related efforts in other jurisdictions and involve other entities in the City's processes, when appropriate. For example, the Johnson Creek watershed spans six different incorporated jurisdictions, and it is important that all of them work together.

Developing Work Plans. Developing detailed work plans is a means of organizing and tracking activities, responsibilities, procedures and resources related to the work to be done in each watershed.[8]

Characterization: Determining Watershed Conditions

Steps 3 and 4 involve determining the following:

- Historical, reference[9] and current (baseline) conditions of watershed health attributes and trends and near-term future conditions[10]
- Landscape and human influences affecting those attributes
- Currently existing watershed problems and assets
- Sources or causes of watershed problems and assets

A watershed characterization is a "snapshot" of historical and current (baseline) conditions and anticipated trends in those conditions.

Step 3: Determine Watershed Conditions

In Step 3, current (baseline) and historical conditions in the watershed are determined, along with anticipated near-term trends in those conditions. Problems that may warrant potential actions—and the causes or sources of those problems—are identified. Similarly, areas where existing conditions provide good, healthy habitat or other important ecological functions (that is, watershed assets) also are identified. These areas may provide opportunities for future actions aimed at protecting and maintaining watershed assets, consistent with Restoration Guideline 3.1. In this step, watershed conditions may be

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[8] The City of Portland's Natural Resources Team is responsible for coordinating the development of watershed management plans. For each watershed, an interbureau technical team will lead the development and management of the scope of work for that watershed.

[9] The concept of reference conditions is discussed in more detail later in this chapter.

[10] For this characterization step, near-term future conditions are those that are certain to occur in the near term (over the next several years) because they are associated with watershed improvement projects that are under way (such as approved highway redevelopment projects, combined sewer overflow projects, etc.).

determined at various scales, from the watershed to the subwatershed and even the reach scale. Products that will result from this stage will include a characterization report for each watershed.

Watershed Health Attributes and Factors That Influence Them. Because ecosystems are complex, it is unlikely that every process and component of the system can be comprehensively described (or characterized). A list of watershed health attributes provides the basis for watershed characterization. Various sources of information, including new or existing data or modeling, are used to evaluate and develop a "profile" of conditions.

Although it is important to describe various watershed health attributes, it is also important to understand and describe the landscape factors and the human activities that influence the watershed health attributes. The set of general watershed health attributes being used by the City of Portland and some of the landscape factors and human activities that influence them are listed in Table 3-1 and discussed in detail in Appendix G.

There is already substantial information about environmental conditions within the City of Portland's watersheds. However, where key information is lacking, the City will take steps to fill data gaps. In some cases modeling may be used, with the understanding that models have limitations and that their output is more reliable the more empirical data they use.

Compilation and Review of Existing Data. During Step 3, available information about current and historical watershed conditions will be compiled from previous studies, databases and inventories. Relevant information to be compiled could include rainfall data, data on flow and water quality, stream survey results, output from hydrologic and water quality models, construction plans of existing facilities, aerial photos, remotely sensed images, topographic maps and geographic information system (GIS) information on land use and land development. In addition, relevant scientific literature will be reviewed to identify the best available science regarding watershed conditions and their effects on watershed processes, functions and resources, particularly in urban and urbanizing areas. Available data describing the watershed health attributes, landscape factors and human influences listed in Table 3-1 will be gathered and evaluated.

Data gathering helps determine watershed problems and assets; data gathering also is a way to assess the adequacy and utility of existing data and identify key data gaps relative to the environmental attributes and key issues. This will help identify any additional field investigations or analyses that are needed to finalize the watershed characterization. Assumptions and gaps will be acknowledged and data limitations documented.

The watershed characterizations will use existing information about environmental conditions and identify data gaps.

During the characterization stage, it is useful to gather information on topics that will become relevant in subsequent steps. This includes information on such topics as social and economic conditions, historical development and regulatory and institutional arrangements. This information enhances understanding of the watershed as a whole and the broad range of factors that affect watershed health. It also can help in identifying and implementing solutions to watershed-related problems. For example, if education and information are key to addressing a problem in a watershed or subwatershed, and many people in that area do not speak English as their primary language, communication tools in languages other than English will need to be developed.

TABLE 3-1
Watershed Health Attributes and Some of the Landscape Factors and Human Influences That Affect Them

Landscape Factors ➔	Watershed Health Attributes 🡐	Human Influences
Climate	**Hydrology**	Land use
Physiography	Hydrograph alteration	Impervious surfaces
Lithology/soils	Floodplain presence and connectivity	Dam impacts
Watershed morphology	Groundwater	Water withdrawals
Hydrology		Drainage network
Vegetation		Channel alterations
	Physical Habitat	Vegetation management
	Floodplain quality and connectivity	Wetland alteration
	Riparian condition: width, composition and fragmentation	Outfall discharges
	Stream connectivity	Exotic species
	Channel condition and habitat structure:	Harassment
	- Habitat types	Harvest
	- Bank erosion	Hatchery management
	- Channel substrate (fine/coarse)	Spills and illicit discharges
	- Off-channel habitat (tributary and side channels)	
	- Refugia (depth, boulders, undercut banks and wood)	
	- Large wood	
	Terrestrial habitat (e.g., oak woodland)	
	Wetland habitat	
	Water Quality	
	Water temperature	
	Dissolved oxygen	
	Nutrients and chlorophyll *a*	
	Total suspended solids	
	Toxic contamination of water, sediments and biota	
	Groundwater quality	
	Other 303(d)-listed TMDL parameters	
	Other parameters (as determined by weight of evidence)	
	Biological Communities	
	Biotic integrity	
	Benthic communities	
	Salmonid population structure (abundance, productivity, spatial structure, diversity)	
	Species interactions (predation, competition, exotic species, etc.)	
	Riparian wildlife	
	Terrestrial wildlife	
	Plant communities	

Modeling and Assessment. In some cases, modeling may be needed to complete the watershed characterization, determine likely reference conditions, identify high-priority watershed problems and well-functioning conditions (Step 4), or analyze management alternatives (Step 7).

Watershed problems and assets will be determined using various means, including modeling to compare existing conditions to properly functioning conditions.

The City is using a number of state-of-the-art models to support its watershed management efforts. For example, water quality monitoring and modeling activities are used to characterize pollutant loading and instream water quality effects. The models focus on parameters for which total maximum daily loads are being established and on other pollutants of concern. Hydrologic and groundwater models are used to assess the potential impacts of different types of stormwater runoff events, such as scour erosion and sediment transport.

In addition to modeling, the City will conduct studies or other analytical work to fill data gaps and better understand conditions in its watersheds. For example, since 1998 the City has sponsored a study of near-shore habitat conditions and fish use in the lower Willamette River, along with studies to evaluate the distribution and biotic integrity of fish populations in key tributaries to the lower Willamette River. The City is in the process of developing a habitat assessment method[11] to evaluate existing conditions as they affect watershed ecosystem health, habitat conditions, fish and aquatic or riparian-dependent wildlife[12] and limiting factors. Additional details about the City's key analytical tools and their uses, including examples, are presented in Appendix H.

Problems

Problems are watershed conditions or features that are not functioning well or that are contributing to impairment of watershed health.

Watershed Assets

Watershed assets are watershed conditions, features or functions that currently are in or near a healthy, well-functioning state, and that are considered key to sustaining important watershed functions. In some instances, they may be at or near reference conditions.

Reference Conditions

… can be defined for each attribute.

… represent the "ideal" conditions for proper or suitable ecosystem function, regardless of urban development or other constraints.

… help define the well-functioning natural conditions that are used to judge the relative health of current and potential future watershed conditions.

… are useful in identifying problems and assets during characterization.

Identifying Watershed Problems and Assets. An important element of characterization involves identifying (1) problems in the watershed that currently are—or may be—obstacles to meeting watershed goals[13], and (2) conditions that are currently healthy (meaning that they are in a well-functioning state), are considered key to sustaining important watershed functions and should be protected in order to achieve those goals. For the purposes of this document, healthy conditions are referred to as watershed assets; they represent conditions that are at or near reference

[11] The City of Portland's habitat assessment method is a multicomponent analytical tool that assesses habitat conditions in the City of Portland's watersheds and determines the effects of these conditions on species' abundance, productivity and diversity. One of the method's components is an adaptation of the Ecosystem Diagnosis and Treatment (EDT) model.

[12] Emphasis is currently on species listed or proposed for listing under the ESA (particularly key salmonid fishes). In the future, the City may expand these analyses to include terrestrial species and their habitat relationships, with emphasis on state sensitive, threatened and endangered species.

[13] Environmental conditions that prevent proper ecological function are sometimes called "key limiting factors".

conditions. Both watershed problems and assets present opportunities for future restoration and protection actions.

Specific types and locations of problems and watershed assets—and the severity of problems or degree of health—will be determined by comparing current conditions with reference conditions that are assumed to be indicative of a healthy watershed. For example, existing stream water temperature may be compared with water temperature criteria established to support growth and production of coldwater biota. As another example, existing streambed substrate conditions may be compared with values reported in the scientific literature for preferred gravel composition conditions for fish-bearing streams. These reference conditions are similar in concept to "normative" conditions as defined by the Independent Scientific Group (2000) for restoration of salmonids in the Columbia River ecosystem or "properly functioning conditions" as defined by NOAA Fisheries (1996) for ESA effect determinations at a watershed scale.

Step 4: Identify the Causes, Sources and Effects of Watershed Problems and Assets

Once watershed conditions have been determined and key problems and watershed assets have been identified, the sources and processes that create them must be determined. To the extent possible, these sources and processes should be quantified.

There is a somewhat subtle but important difference between causes and sources. Causes are the inputs or conditions that result in effects, whereas sources produce or generate the inputs or conditions. For example, discharge from the storm drainage pipe system into the stream channel may be the *source* for increases in high flows, which are a *cause* of streambank erosion at specific downstream sites.

Causes are the inputs or conditions that result in effects, whereas sources produce or generate the inputs or conditions.

Identifying the sources or causes of watershed problems and assets is challenging for three primary reasons. First, often a large number of potential sources or causes underlie a particular situation. Second, there can be large gaps in data about the relative contributions of different possible sources or causes across a watershed. Third, watershed processes and their dynamics are complex.

In spite of these challenges, identifying the sources or causes of watershed problems is critical to developing effective solutions. Solutions will be successful only if they address the most significant sources or causes and are designed to account for the variability of those sources and causes over time and space (see Restoration Guideline 3.3). Similarly, understanding why watershed assets exist is key to maintaining them. For example, the causes of cool stream temperatures may be the presence of shade trees and low amounts of impervious surfaces. To maintain the desirable stream temperatures, it will be necessary to protect the conditions that cause them—that is, to maintain the shade trees and continue to limit impervious surface area.

Efforts to identify the sources or causes of watershed problems and assets will be enhanced by the following:

- **A comprehensive understanding of the ecosystem and the processes that affect the condition of each of its environmental attributes.** This is developed by understanding the latest research findings on environmental attributes and watershed processes, as well as the scientific principles and restoration guidelines in Chapter 2. This includes an understanding of natural watershed functions and processes, and the role and effects of the surrounding built environment (that is, urban and urbanizing areas and their associated human activities and infrastructure).

- **An accurate characterization of the key problems in a watershed and the dynamics of these problems over time and space.** This is developed through the watershed characterization (see Step 3), which encompasses both the natural and built components of the environment, and by understanding the concepts of indicators and reference conditions. These are described in Step 6 and Appendix G.
- **Development and refinement of analytical tools and information that can be used to link human activities across the watershed to their impacts within the riverine-riparian environment.** The City of Portland uses analytical tools to evaluate conditions and activities within and across the watersheds' riverine-riparian environment.[14] These tools, which are described in Appendix H, can be used to evaluate the causes and relative impacts of problems identified during watershed characterization and the sources of conditions that create protection or restoration opportunities; over time the analytical tools will be refined.
- **Focused analyses to verify and further characterize causes and sources.** The City will conduct focused analyses to further verify and characterize potentially important sources so that more effective solutions that will address them can be designed. Such analyses may include site-specific data collection or the use of models to better characterize particular sources or causes of watershed problems. Identifying the origins of watershed problems and the conditions creating watershed assets may also involve iterative calculations or modeling runs to assess which problems, watershed assets, causes and sources have the greatest effect on the watershed indicators.
- **Expert opinion.** Sometimes it is desirable to enhance understanding or fill data gaps by consulting academic institutions, governmental agencies and others with expertise in various areas related to watershed health processes and attributes. There are various ways of tapping into such resources, including workshops such as those conducted by the Center for Watershed Protection.[15]

Cause-Effect Links. A cause-effect link will be established for each watershed problem or asset, to the degree possible. This link will identify the causes of each problem, the reasons for each healthy condition, and the effects of each problem or healthy condition on specific watershed resources or features. Identifying cause-effect links helps set the stage for Step 5, when objectives are developed; Step 6, when indicators are selected; and Step 7, when potential actions are identified. An example of the link between an identified problem and its specific causes and effects is presented in the top portion of Figure 3-2. Similarly,

[14] The City may develop and apply additional tools to address the terrestrial components of the ecosystem.

[15] The Center for Watershed Protection, based in Baltimore, Maryland, is a nonprofit, nonadvocacy organization that works with watershed groups and governments to help them understand and protect urban watersheds. One of the approaches the center uses is that of community workshops that bring together professionals with expertise in a variety of fields related to watershed health.

linkages between an identified watershed asset and reasons for that asset's existence, along with the asset's effects, are shown in the bottom of Figure 3-2.

To determine cause-effect relationships, the City will identify the following:

- The types and locations of the problem or conditions and the resources that are or may be affected (from Step 3)
- The types and locations of watershed processes or inputs of pollutants or materials (such as fine sediments, nutrients or thermal energy) involved in the problem or condition (from Step 4)
- The mechanism of effect or impairment to these resources (from Step 3) and activities and/or "trigger events" that cause or contribute to the effect (such as a storm event that increases runoff and thus causes erosion) (from Step 4)

FIGURE 3-2
Cause-Effect Relationships for a Sample Problem and a Sample Asset

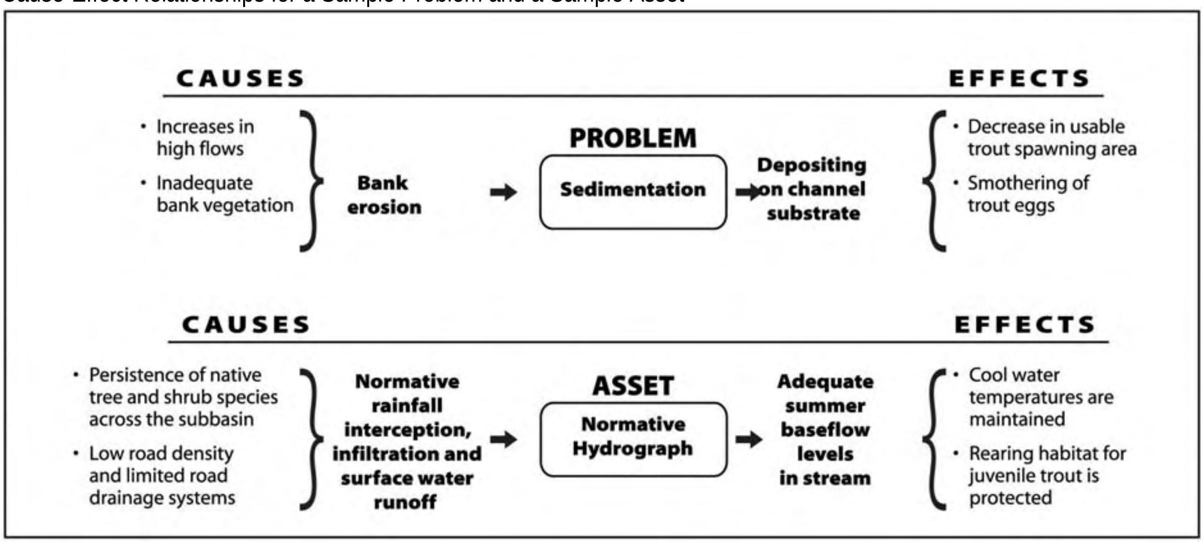


Table 3-2 shows an example of how these cause-effect links will be established during characterization. The links can result in the development of problem and asset statements (as shown in the examples in Table 3-2) that specifically describe the linkages between causes and effects. The cause-effect links also can identify specific sources, if known, that cause problems or produce assets. These sources include the inputs, activities or events that trigger a problem or maintain an asset.

Specific watershed problems or assets and their causes and sources may be grouped based on the type of healthy condition or problem, magnitude of effect, correlation with watershed health goals or restoration guidelines, degree of benefit from a single potential solution or action, or other factors.

Some projects may proceed directly to implementation, if they are well justified and the conditions they address are well understood.

In cases where problems or watershed assets exist and are well understood, or where projects and actions are already well justified as a result of previous planning efforts, projects and actions may proceed directly to implementation.[16]

TABLE 3-2
Components and Sample Details for Identifying Watershed Problems or Assets and Their Causes, Sources and Effects

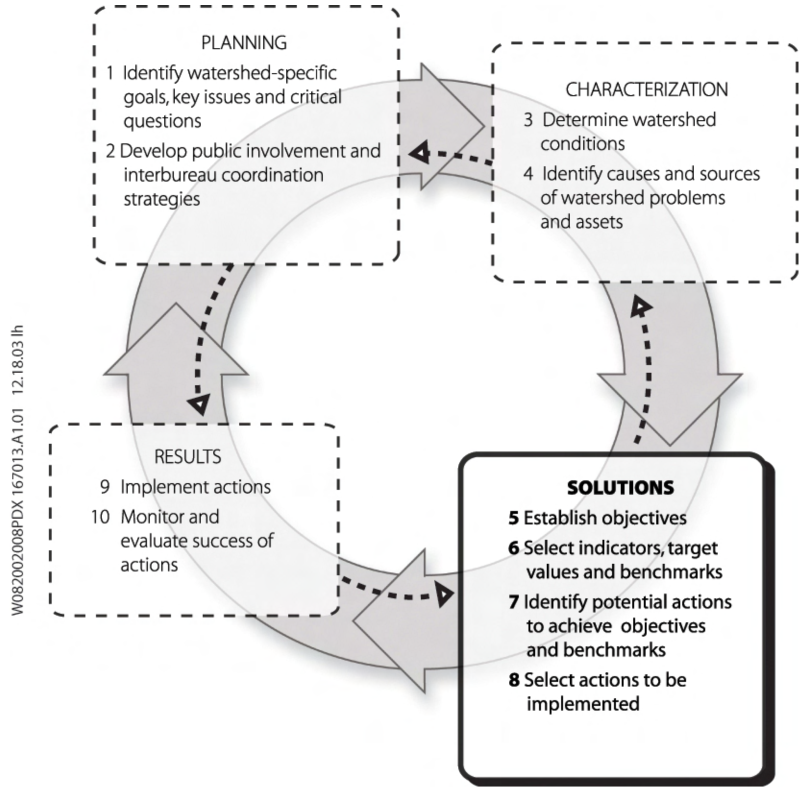
Step	Components	Example
Identify the problem or watershed asset (Step 3)	Location of the problem or asset Resource(s) affected Effects on the resource(s) Input causing the effect Means by which the input affects the resource(s)	**Sample Problem:** Fine sediment deposition on channel substrate in lower Balch Creek reduces cutthroat trout productivity by decreasing usable spawning area and reducing oxygen available to eggs in trout redds. **Sample Watershed Asset:** A normative hydrograph in Miller Creek provides adequate summer baseflows for maintaining cool water temperatures and rearing habitat for juvenile trout.
Identify the causes and sources of the problem or watershed asset (Step 4)	Input delivery process Location of the process Types of activity or events causing the problem or maintaining the conditions	**Sample Causes and Sources of the Problem:** A sediment budget indicates that the key causes of fine sediment deposition are streambank erosion within the Balch Creek subbasin resulting from increased high flows and inadequate bank vegetation. The source of the increased high flows is stormwater runoff from impervious surfaces in a particular part of the subbasin. The source of inadequate bank vegetation is sparse plant establishment at the erosion sites themselves. **Sample Causes and Sources of the Watershed Asset:** Dense vegetation cover and low amounts of impervious surface area in the Miller Creek subbasin allow for rainfall interception, groundwater recharge and surface runoff to Miller Creek in a manner that resembles a relatively undisturbed forested system.

Solutions: Establishing Objectives, Targets and Benchmarks and Identifying Actions to Achieve Them

The next four steps involve identifying watershed-specific objectives for each goal, selecting indicators for measuring watershed health conditions, establishing targets and benchmarks for those indicators, and recommending and selecting appropriate actions.[17]

16 Design, budgeting, permitting, socioeconomic analyses and other tasks may need to be completed before projects and actions are implemented.

17 The word “actions” is used broadly and can include capital expenditure projects, programs (nonregulatory or incentive-based) or other projects.



Step 5: Establish Watershed-Specific Objectives

Achieving goals that essentially call for "healthy watersheds" necessitates development of clear objectives that will lead to appropriate and effective actions. To do this, objectives must be specific in describing the functions and conditions that are desired at some point in the future. Objectives will be set for each watershed-specific goal. It is likely that there will be several objectives for each goal. Taken together, the objectives will describe the outcome that must be achieved for a watershed health goal to be attained.

> **What are objectives?**
> Objectives are specific outcomes in watershed functions and conditions that must be achieved for watershed health goals to be attained. An objective is a measurable component of a goal.

The problem and asset statements (such as those shown in Table 3-2), which reflect the linkages among sources, causes and effects, point the way toward development of restoration or protection objectives. For example, using the problem and asset statements shown in Table 3-2, objectives might be initially developed as follows:

- **Sample Objective for Physical Habitat Goal:** Reduce erosion-caused sedimentation in the channel substrate, to enhance cutthroat trout spawner and juvenile production in lower Balch Creek.
- **Sample Objective for Hydrology Goal:** Maintain normative summer baseflow conditions to protect cool water temperatures and cutthroat trout rearing habitat in Miller Creek.

Establishing objectives sets the stage for identification of indicators in Step 6. In some cases there will be more than one indicator for each objective, as in the following:

- Sample Objective: Increase the quality and quantity of the riparian buffer area along the middle reach of Johnson Creek to increase nesting habitat for songbirds and to provide shade and large wood recruitment for aquatic species.

It is likely that there will be several objectives for each goal, and possibly several indicators for each objective. Taken together, the objectives and indicators will describe the outcome that must be achieved for a watershed health goal to be attained.

Indicators for this objective could be riparian buffer width and vegetation composition.

As Step 6 is performed, the objectives will be refined (if possible), indicators and target values will be selected, and timelines will be established, making the objectives more measurable and specific. However, in some cases information may not be available to further refine an objective. Such an objective may remain less specific and more qualitative but nonetheless be important in identifying indicators in Step 6.

A method for refining objectives and also for ensuring that the City will consistently identify indicators, target values and timelines is through the use of "word templates" as shown in Table 3-3. This method is introduced here (although it cannot actually be completed until much of Step 6 is performed) to provide the reader with an understanding of the level of detail the City will use when performing Steps 5 and 6. Whenever possible, the "word template" components will be identified in specific, quantitative terms. Even for an objective that must remain less specific and more qualitative, the word template ensures consistency in the format and components of an objective.

The word template examples show the various components necessary for a clear, measurable objective, specifically:

- The attribute to be changed or protected (indicator)
- A target or desired condition (a measurable endpoint for the indicator)
- A spatial scale
- A time frame for achieving the change in the indicator

The examples in Table 3-3 also identify links to biological or ecological functions. This identifies the specific environmental process or feature at which the objective is aimed, such as a particular species (cutthroat trout, for example), a type of habitat (juvenile rearing habitat) or physical or ecological process (summer baseflow accretion).

The value of refining objectives in this manner is to make clear the desired outcome with respect to the problem or condition responsible for an affected resource.

TABLE 3-3
Sample "Word Template" for Refining Watershed-Specific Objectives

Objective Components	Example Elements
Attribute (Indicator)	fine sediment
Target or Desired Condition—Measurable Endpoint of Attribute	reduce streambed sediment embeddedness to 20% or less
Linkage to Biological/Ecological Functions	to support cutthroat trout spawning and egg incubation
Spatial Scale	in lower Balch Creek
Time Frame	by 2040
Refined Example Objective for Physical Habitat Goal: Reduce streambed fine sediment embeddedness to 20 percent or less in lower Balch Creek by 2040 to support cutthroat trout spawning and egg incubation.	
Objective Components	**Example Elements**
Attribute (Indicator)	summer baseflows
Target or Desired Condition—Measurable Endpoint of Attribute	increase to levels that maintain water temperatures (at less than 64^{o} F) and habitat availability
Linkage to Biological/Ecological Functions	to support cutthroat trout rearing
Spatial Scale	throughout Miller Creek
Time Frame	by 2060
Refined Example Objective for Hydrology Goal: Increase summer baseflows to levels that maintain water temperatures (at less than 64^{o} F) and habitat availability throughout Miller Creek by 2060 to support cutthroat trout rearing.	

Step 6: Select Indicators and Establish Target Values and Benchmarks

To be able to track progress in achieving goals and objectives, it is necessary to select clear, measurable, scientifically based environmental indicators, along with targets and benchmarks for those indicators. These will be derived from an examination of the objectives established in the previous step and should provide the City with a way to determine whether those objectives are met.

The potential indicators presented in Appendix G will serve as a starting point for identifying appropriate watershed-specific indicators.

Environmental Indicators. Because of the complexity of ecosystems, it is not possible to measure the condition of, or changes in, every component of the system. The concept of indicators addresses these challenges. An indicator is a readily measurable attribute that captures the condition and dynamics of broader, more complex and less readily measurable attributes of ecosystem health. Indicators are often focused on structural and compositional components of the ecosystem, rather than directly on processes or functions (Mulder and others 1999). This is a matter of practicality rather than priority. For example, it is easier to measure the width, vegetative composition and connectivity of a riparian area than to measure the myriad complex functions that the riparian area provides (such as maintaining water quality, providing microclimates and supplying organic inputs into the food web).

The City of Portland has assembled a set of potential indicators that comprehensively address the structure of, function of and impacts to local urban watersheds (see Table 3-1, which lists the indicators in the center column, titled "Watershed Health Attributes," and Table G-1 in Appendix G).[18] These indicators were adapted from NOAA Fisheries' Matrix of Pathways and Indicators (National Marine Fisheries Service 1996b) for high-gradient, forested landscapes and the list of watershed health attributes and influences discussed in Step 3 and in Appendix G. The list of indicators serves as a starting point for identifying appropriate watershed-specific indicators.

Based on the information assembled and analyzed during characterization of watershed conditions, some indicators may appear to be more relevant than others. For this reason, the list of indicators that are selected for measuring watershed health in a particular watershed or subwatershed will reflect the specific conditions and priority problems of that watershed. The indicators also will be the basis for how the City will measure whether the objectives for each watershed health goal is met. It is likely that some indicators will serve to measure the health of more than one objective. For example, improvements in riparian conditions may indicate progress in achieving both physical habitat objectives and biological communities objectives.

Some indicators, such as riparian conditions, may be useful in measuring progress in achieving more than one objective, such as physical habitat objectives and biological communities objectives.

Because indicators are the means the City will use to determine watershed health, it will be necessary to monitor them to determine whether changes have occurred over time (see Step 10 for details about monitoring). However, in some cases, changes in an indicator may be difficult to detect on a frequent basis. It may take years or even decades before actions actually result in improvements in the indicators. Additionally, it may be challenging to determine whether an action actually produces the desired change in the indicator (for example, whether certain stormwater management practices have contributed to specific reductions in stream peak flows, or whether planting several hundred trees actually reduces stream temperature).

Although it may be easier to measure and monitor changes in land use or percent of effective surfaces as "surrogates" of indicators, the risk in this approach is that there might not be a strong correlation between a surrogate and an indicator. The benefits, on the other hand, might be that a surrogate could address several indicators at the same time. For example, reductions in percent effective impervious surface could result in improvements to several indicators, such as hydrograph alteration, water temperature, total suspended solids and certain biological communities. Therefore, the way the City tracks changes in watershed health may include a combination of environmental

Ultimately, it is the change in conditions and functions that the environmental indicators represent that will be the true measure of watershed health.

[18] The watershed health indicators in this *Framework* focus on the health of key watershed processes, especially hydrology, aquatic and riparian habitats, water quality and biological communities. Although the primary ecological principles; many aspects of the riverine, wetland and upland ecological principles; and the restoration guidelines apply to terrestrial species and habitats as well as to aquatic; additional indicators to address terrestrial components of the ecosystem still need to be developed. The City of Portland recommends that these indicators be developed in the near future (see Chapter 4).

indicators (see the "Watershed Health Attributes" column of Table 3-1) and surrogates that are reflective of the human influences listed in Table 3-1. Ultimately, however, it is change in the environmental conditions and functions that the indicators represent that will be the true measure of watershed health. The rationale for the selection of environmental indicators is discussed in greater detail in Appendix G.

Reference Conditions. Although the City acknowledges from the outset that it will not be possible to return to "pristine" conditions that were present before European settlement of the Pacific Northwest (particularly in a highly urbanized area such as Portland), it is important to understand and describe the conditions of attributes described during characterization—and those that are ultimately selected as indicators in Step 6—that represent healthy conditions. This is similar in concept to, for example, "normative" conditions as defined by the Independent Scientific Group (2000) for restoration of salmonids in the Columbia River ecosystem or "properly functioning conditions" as defined by NOAA Fisheries in its Matrix of Pathways and Indicators.[19] These reference conditions reflect the watershed's natural ecological potential, meaning the conditions that would exist if all environmental attributes were unimpaired and functioning properly. Reference conditions do not necessarily become targets to be met, but comparing reference conditions to current conditions is useful in guiding the development of targets.

Reference conditions do not necessarily become targets to be met. More often, they will be used to guide the development of targets.

A challenge in determining reference conditions relates to the dynamic and unique nature of ecosystems. Even within pristine and fully functioning ecosystems there are wide ranges of conditions, and this greatly complicates attempts to describe "ideal" or "healthy" conditions. Using the analogy of human health, a healthy 25-year-old person exhibits characteristics that are different from a healthy 75-year-old person. Similarly, two healthy 25-year-old people can exhibit different conditions. A condition that is healthy for one watershed or stream reach may be unhealthy for another. Some stream reaches, for example, are depositional areas that naturally accumulate high levels of sediment, while in other reaches, sediment accumulation is a sign of highly degraded conditions resulting from excessive upland and instream erosion. Additionally, the amount of wood that naturally accumulates in a stream may vary widely as a result of localized differences in gradient, flow, stream morphology and riparian conditions.

Given this natural heterogeneity, it is difficult—and in many cases inappropriate—to identify a single value for an indicator that unambiguously defines healthy conditions across all stream reaches and watersheds. Reid and Furniss (in press) argue that even an attribute as straightforward as water temperature is probably not appropriately addressed by using a single value to define a condition that is well functioning, given the wide range of natural variability in temperatures across a watershed and salmon's behavioral adaptations to use thermal refugia. Bauer and Ralph (1999) make the case that these arguments are even more germane when applied to habitat indicators, where defining a single value that delineates "good" conditions is far more ambiguous. Even within pristine watersheds, cycles of disturbance and recovery regularly result in localized patches of

[19] National Marine Fisheries Service 1996.

habitat that would be considered unhealthy if measured against habitat targets, yet such processes are critical for watershed health and habitat formation (Bisson and others 1997, Reice 1994).

To address the heterogeneity of conditions in watersheds and the fact that a particular indicator of stream health could exhibit a range of values through space and time, Mulder and others (1999) propose that a distribution of values for a particular indicator be used in defining values that represent suitable and well-functioning conditions. The difficulty with this approach is determining the distribution of values. Mulder and others (1999) suggest the following:

- Using historical conditions to inform the process of setting appropriate values or ranges of values for each indicator
- Using reference areas to define the range and variability in ecosystem indicators that would be expected in ecosystems that are unaffected or minimally affected by human activities
- Using models to provide insight on historical conditions

Each of these approaches has its limitations. Data on historical conditions are sparse and not likely to be available for all of the indicators used to assess watershed health. It may be difficult to find reference watersheds that are minimally affected and comparable to local urban watersheds. And while models can provide valueable insight, their output on historical conditions cannot be validated and so must be used with caution. Given the limitations of each individual approach, it would be prudent to use the various approaches in conjunction with one another to develop a more robust understanding of the distribution of conditions that would be expected in a healthy watershed.

Reference conditions merely guide the development of target values, rather than serve as rigid levels below which the ecosystem is unambiguously defined as degraded. Ultimately, achieving watershed health will depend on the restoration of ecological processes, not on a set of indicators reaching specific measurable values.

Reference conditions for indicators of watershed health should be used cautiously to guide establishment of targets and desired conditions. They are not intended to be used in the same manner as, for example, water quality standards; that is, they are not rigid lines below which the ecosystem is unambiguously defined as degraded and above which it is healthy. In particular the reference conditions should not be considered rigid "ideals" to which all reaches of a watershed should conform or else the protection and restoration efforts are labeled a failure or incomplete. As the City's understanding of watershed processes increases, the appropriate reference conditions will evolve over time. Confidence in them will increase until they can be used more extensively in providing specific guidance for refining targets and desired conditions, as well as protection and restoration efforts.

The City of Portland intends to use reference conditions in three ways:

- As a way to evaluate the general nature and severity of environmental problems in a watershed and the nature and degree of watershed assets

- To indicate the direction and general magnitude of the restoration and protection efforts needed to restore watershed conditions to meet stated city goals, objectives and obligations
- As measuring sticks that aid in the interpretation of characterization and monitoring data

The most important point that must guide the use of indicators and reference conditions is that they are used to represent underlying physical and ecological processes that affect watershed health. As measurable reflections of complex ecological processes that are difficult to measure directly, the City can use indicators and reference conditions to evaluate how well these processes are functioning and as "useful signals of environmental degradation" (Bisson and others 1997). Ultimately, however, it is the integrity of the ecological processes that is required to restore watershed health, rather than a set of indicators reaching specific measurable values.

Target Values or Desired Conditions. The City of Portland will establish target values—or desired conditions—for each of the selected environmental indicators at a watershed level and, when possible and practical, at the subwatershed level or even stream reach level. These target values are based on what is necessary to achieve healthy watersheds, tailored to that specific area. Although many of the environmental indicators will be the same from one watershed to the next, the target values for those indicators may vary to reflect the unique physical and biological conditions of each watershed. For example, if a particular stream historically never had large amounts of woody debris, it does not make sense to establish target values that call for amounts above historical levels.

What are target values and desired conditions?

Target values and desired conditions are those conditions that the City of Portland will ultimately strive to achieve in order to meet its watershed health goals and objectives. Target values are based on what is necessary to achieve healthy watersheds while at the same time taking into account aspects of the urban environment that, for practical purposes, are unchangeable.

Target values and the benchmarks that will be established from them will provide the means for determining whether the City of Portland has achieved its watershed health objectives and goals. The relationship among reference conditions, current (baseline) conditions, target values and benchmarks (which are discussed more fully below) is shown in Figure 3-3.

In many cases, the target values—or desired conditions—for each of the selected environmental indicators will actually be represented by a range rather than by a single value (see Figure 3-3). A range recognizes that particular environmental attributes can be in a healthy state over a certain range of conditions. For example, Sullivan and others (2000) report that preferred water temperatures for steelhead growth occur over a range from about 10^{0}C to 17^{0}C (50^{0}F to 63^{0}F). The Oregon Department of Fish and Wildlife's (ODFW) habitat inventory protocol specifies that the most desirable distance between pools for productive salmonid habitat is equal to between five and nine channel widths.

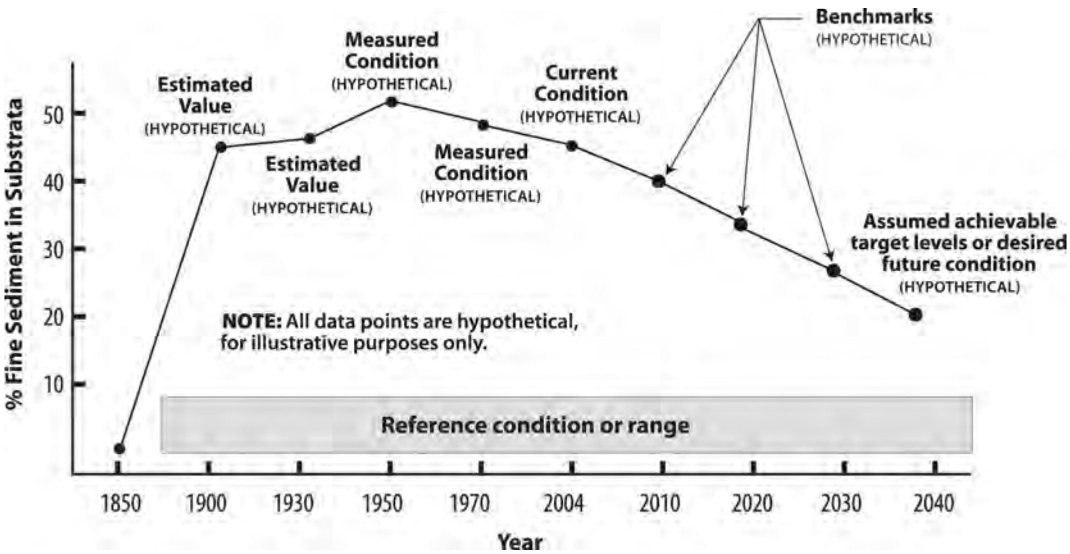


FIGURE 3-3
The Use of Reference Conditions, Target Values and Benchmarks

The target values should also take into account major physical, social or financial limitations, particularly those posed by an urban environment. As such, the target values represent a proper level of function for an urban environment, taking into account aspects of the urban environment that, at this time, given current societal values and priorities, are considered unchangeable. For example, significant areas within the City's watersheds contain impervious surfaces from which drainage is routed to stormwater or combined systems. Such areas generate storm runoff that is much higher and more frequent than would occur naturally. This affects stream flow, water quality and channel habitat conditions preferred by salmonids. Target values would represent assumed best-case watershed functions and conditions, taking into account these continuing effects of urban development.

Target values should take into account physical, social or financial limitations, especially those posed by an urban environment.

In effect, target values are based on reference conditions (as described above), adjusted to take into consideration what is realistic and practical, particularly in light of constraints imposed by the watersheds' urban and urbanizing settings. Once the indicators and associated target values or desired conditions have been established for a particular watershed (or subwatershed), the objectives for that watershed can be refined. Refined objectives should specify the spatial scale (if it is not watershed-wide) and a time frame for completion, as shown in Table 3-3.

Because the City of Portland will be monitoring the condition of selected indicators over time, it will be able to measure changes in hydrology, habitat and water quality; measure the response of salmon and other aquatic and nonaquatic populations to these changes; determine whether the target values need to be adjusted to better meet objectives; and determine whether a specific objective is ultimately achievable. This process of gathering data and applying adaptive management will ensure that the values evolve into appropriate measures of health for local watersheds.

As the City of Portland makes progress in restoring its watersheds (in terms of both structure and function) so they more closely resemble properly functioning conditions, increased understanding and adaptive management will allow the target values to be adjusted to reflect the state of the science.

Some important assumptions underlie the concept of establishing targets and desired conditions:

From Goals to Actions

Citywide and watershed-specific goals
↓
Watershed-specific objectives
↓
Watershed-specific watershed health indicators
↓
Reference conditions for selected indicators
↓
Desired conditions or target values for selected indicators
↓
Watershed-specific benchmarks for selected indicators
↓
Restoration and protection actions and monitoring of indicators

- The requirements for healthy watersheds and populations of fish and other aquatic and nonaquatic organisms do not change based on the land uses surrounding them. Whether the surrounding landscape is urban, agricultural or forested, fish (for example) still need cool, clean water and suitable habitat. Until studies clearly demonstrate that genetic adaptations have changed local physiological requirements or watershed functioning, it should be assumed that healthy watersheds and biological communities in urban areas require the same underlying conditions as do healthy watersheds and biological communities surrounded by other land uses. However, how these functions and conditions manifest themselves in an urban area may be different from how they manifest themselves in a pristine area. In other words, in an urban area, it will be important to achieve the same function, but the form that function takes may be very different. For example, achieving healthy watershed conditions may entail running stormwater through a settling basin and treatment swale rather than through a vegetated riparian zone. In fact, it is preferable to concede that full watershed health may not be attainable in all parts of the urban area than to adjust the definition of a healthy watershed in an urban area without a sound body of research to support that adjustment.

- A normative ecosystem is possible within an urban landscape. As discussed under Salmonid Ecology Principle 3, an urban landscape that contains a mix of natural and cultural features that typifies modern society can sustain all life stages of a diverse suite of salmonid populations if that landscape provides essential ecological processes and conditions.

- Although watershed-specific targets for indicators should be realistic, they should not be set short of what is considered to be healthy for that watershed merely because the objectives do not seem attainable in the near future under existing urban conditions and constraints. The ways in which development occurs are continuing to evolve, as are scientific knowledge of watershed processes and the

What seems unattainable now may become attainable over time, and what seems easily attainable now may prove to be more difficult than expected.

tools and techniques for protecting watersheds. Therefore, what seems unattainable now may become attainable over time, and what seems easily attainable now may prove to be more difficult than expected. That said, targets should not be so unrealistic as to be irrelevant to management decisions. Similarly, benchmarks—as described below—should reflect existing conditions, constraints, effects on other priorities and the known effectiveness of potential management actions.

Watershed-Specific Benchmarks. As discussed earlier, objectives and targets should be reflective of urban constraints. Given the reality of conditions and constraints in the City's urban and urbanizing watersheds, it probably will take several decades to achieve watershed-specific targets and objectives. Therefore, the City will establish benchmarks that define interim targets to be achieved over time. Benchmarks provide a practical way in the watershed management process of measuring progress in achieving objectives—and ultimately watershed health goals. Benchmarks add an interim time component to achieving objectives and become the "measuring stick" for assessing progress. They are important tools in communicating what the watershed indicators should "look like" at specific time intervals. Benchmarks also assist planners in prioritizing actions for implementation and are critical for adaptive management.

The concept of using benchmarks to measure progress in achieving objectives is depicted in Figure 3-3. The figure also shows the relationship of benchmarks to desired conditions or target values, which may actually be a range of values.

Progress in meeting objectives and benchmarks will inevitably vary, depending on the indicator. For example, it may be possible to achieve temperature standards in a certain subwatershed or stream reach sooner than in others. Benchmarks can be sensitive to those differences. They also can reflect watershed health priorities within the watershed or subwatershed.

Benchmarks should be realistic, should reflect the realities of the built environment, and should be selected recognizing that social and institutional constraints may limit progress in achieving objectives. For example, the selection of benchmarks can take into account limitations posed by such factors as funding, sequencing of actions and other City goals and priorities. Examples include court-ordered capital programs, existing federal facilities such as dams and highways over which the City has no legal control, and the need to protect human

What are benchmarks?

Benchmarks are specific outcomes that must be achieved at specific times for watershed health objectives to be attained.

Benchmarks provide a means of tracking progress in achieving watershed health objectives and goals.

Benchmarks consist of three primary components: (1) the environmental indicator at which the objective is directed, (2) a value that reflects a target, meaning a desired condition or response in the indicator, and (3) time frames for reaching those targets or conditions.

Example: *Physical Habitat*

Goal*:* Protect, enhance and restore aquatic and terrestrial habitat conditions to support key ecological functions and improved productivity, diversity, capacity and distribution of native fish and wildlife populations and biological communities.

Objective: Reduce the percentage of fine sediments in the riffle substrates of Balch Creek to 20 percent by the year 2040.

Indicator: Percent of fine sediments in riffle substrate

Reference condition: 12% or less

Target: 20% or less by 2040

Benchmarks: 35% by 2010
30% by 2020
25% by 2030 health and safety and the integrity of critical city infrastructure. On the other hand, recognition of such limitations may not necessarily dictate setting less ambitious benchmarks, but rather that other solutions to problems need to be pursued. It should be noted that setting ambitious benchmarks can be used to attract public support and funding for projects and programs that help achieve those benchmarks.

Establishing benchmarks should take into account the anticipated effects of current projects and efforts already under way that will improve water quality and stormwater runoff conditions. Examples include the City's combined sewer overflow (CSO) project and the Downspout Disconnect Program. Benchmarks should also take into account the anticipated effects of events, such as population growth, that may result in negative effects.

Benchmarks will be set to correspond to the expected rate of progress in achieving an objective, even if that progress is uneven or delayed, as with trees planted to shade streams and reduce water temperatures.

For all of the above reasons, the benchmarks that are established may not always follow as linear a path as that depicted in Figure 3-3. As an example, it could take 50 years for trees planted now to start shading streams enough to have a cooling effect on water temperature. In this case the benchmarks for the indicator (water temperature) would be set at roughly the same level for the first four to five decades but would be set progressively lower for the next few decades, to correspond with the expected expansion of the tree canopy over the stream. In other situations benchmarks might even reflect anticipated declines in the condition of an indicator, depending on what is realistically achievable.

As with the objectives, benchmarks will be evaluated and adjusted periodically as new information is collected and the City's understanding of its watersheds and watershed health science improves.

Step 7: Identify, Evaluate and Prioritize Actions to Achieve Watershed Health Objectives and Benchmarks

Step 7 involves identifying, evaluating and prioritizing potential actions according to how well they achieve watershed health goals, objectives and benchmarks. Because there are usually multiple ways of achieving goals, objectives and benchmarks, a process of identifying and selecting the most desirable and effective actions is necessary. This step entails developing a "long list" of potential actions and paring it down to a "short list" of actions that will be considered for implementation.

Potential Actions. After watershed-specific objectives, targets and benchmarks have been developed, potential actions and projects that address them will be identified. Understanding the reasons or causes of a watershed problem (or reasons why an asset exists) will help in determining appropriate actions in Step 7. For example, increasing bank vegetation may be important to achieve certain stream temperatures in a specific stream reach, but it may also be important to reduce stormwater runoff from paved surfaces. There are likely to be a variety of specific actions that can address the underlying causes or problems, but selection and prioritization of actions should be based on targets and benchmarks that are established in Step 6 and on analyses, evaluations and other factors described in Step 7.

An initial set or list of potential actions and projects will be identified from four main sources:

- **The results of the watershed characterization** performed in Steps 3 and 4, particularly the preliminary action strategies that are identified as problem and asset statements and cause-effect linkages are determined.
- **City projects.** Various City staff will identify actions or projects currently under way—such as TMDL, public facilities and parks management—that could be effective at improving watershed health. Other projects may be identified that have yet to be designed, funded or implemented but should be considered at this stage.
- **Entities and stakeholders working in the watersheds.** Potential actions and projects will be solicited from entities and stakeholders in the watersheds. The "smart watershed program" developed by the Center for Watershed Protection may be useful in identifying potential opportunities for protection.[20] That program involves holding facilitated workshops that are attended by both city employees and multiple stakeholders within the watershed.
- **Scientific literature.** Scientific literature will be reviewed to identify strategies and actions that have been implemented elsewhere to address similar watershed conditions.

It is important that a variety of potential actions be considered; if problems are to be corrected and watershed assets are to be protected, a "one-size fits all" approach will not be effective. Potential actions could include a combination of capital expenditure projects, programs and initiatives, regulations and other actions and projects, as follows:

- **Capital expenditure projects:** Specific on-the-ground projects (structural or nonstructural) requiring capital expenditures. Examples include habitat restoration projects, land acquisition and stormwater treatment wetlands.
- **Programs:** Specific programs or initiatives that include nonregulatory or incentive-based mechanisms for addressing watershed and river health. Examples include outreach and education, technical assistance, conservation easements or purchase of development rights.
- **Regulations:** Development of, or modifications to, ordinances or codes intended to regulate land uses or development affecting water quantity, water quality, riparian conditions or stream channel/habitat conditions. An example is zoning codes. (Regulations are included in this list not because the City intends to impose additional or costly restrictions on private property as a way of achieving its watershed health goals; rather, regulations are included because they are one of many factors that affect watershed health, and because potential changes in regulations could complement other watershed protection and restoration actions the City expects to take, such as education, incentives and on-the-ground projects.)

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[20] This process is tailored especially to small watersheds or subwatersheds of between one and five square miles in size. The Center for Watershed Protection, based in Baltimore, Maryland, is a nonprofit, non-advocacy organization that works with watershed groups and governments to help them understand and protect urban watersheds. One of the approaches the center uses is that of community workshops that bring together professionals with expertise in a variety of fields related to watershed health.

- **Other Actions and Projects:** Various other actions and projects that do not fit conveniently in the three classes above. Examples include research, demonstration or pilot projects, monitoring, modeling or technical reports to inform existing or future plans or management practices. Examples might also include changes in City maintenance activities, such as street sweeping, or vegetation management in City parks.

It may be useful to group potential actions gleaned from these sources into general categories and, within each category, to group them by type of action and location, if possible. Such groupings are expected to provide a more efficient means of analyzing, justifying and recommending potential actions at the watershed or citywide scale. Specific actions will be selected for evaluation, with the result being a comprehensive, preliminary "long list" of specific actions or projects from which alternative sets of actions can be formulated. Table 3-4 provides examples of possible watershed actions or projects, organized by general category and type of action or project. Some actions lend themselves to basinwide application, while others are more suitably applied on a site-specific basis.

TABLE 3-4
Examples of Possible Watershed Actions or Projects, Organized by General Category and Type

General Category	Type of Action or Project	Examples of Possible Actions or Projects
Land Conservation	Land acquisition Conservation easements Vegetative buffers Vegetation management Stewardship	
Site Design	Open space and cluster development Green streets, lots and curbs	
Stormwater Runoff Management	Pollutant source reduction Stormwater infiltration Erosion control Water volume management Water quality treatment →	Possible actions or projects: • Biofiltration swale • Bioretention system • Constructed wetland • Extended detention pond • Infiltration basin • Riparian forest buffer • Sediment basin
Non-Stormwater Discharge Management	Septic system management Sanitary wastewater collection system Sanitary wastewater treatment Illicit discharges management	

TABLE 3-4
Examples of Possible Watershed Actions or Projects, Organized by General Category and Type

General Category	Type of Action or Project	Examples of Possible Actions or Projects
Habitat Protection and Restoration	Instream habitat restoration	
	Bank protection and restoration	Possible actions or projects: • Bank shaping and revegetation • Brush layering • Gully repair • Log, rootwad and boulder revetment • Riparian plantings • Tiered wall/bench plantings • Tree preservation and protection
	Riparian/wetland habitat protection and restoration	
	Upland habitat protection and restoration	
	Tree protection and restoration	
	Invasive species management	
Watershed Stewardship	Outreach and education	
	Incentive programs	
	Pollution prevention	
	Watershed maintenance	
	Research, monitoring and adaptive management	
	Coordination with other agencies and jurisdictions	
Managing Land Use and Development	Overlay zoning	
	Urban growth boundary	
	Large lot zoning	
	Landscape standards	

Evaluating Potential Actions. The preliminary "long list" of potential specific actions or projects (developed as described above) will be analyzed in terms of how well the actions align with the restoration guidelines presented in Chapter 2 and how effective they are in achieving benchmarks and objectives across a watershed or subwatershed. Similarly, projects will be evaluated based on how they support or conflict with other actions and projects, environmental and otherwise. Potential projects and actions that conflict with other priorities—public and private—will receive lower overall ratings than potential projects and actions that don't conflict.

Potential actions will be evaluated in terms of how well they align with the restoration guidelines, achieve benchmarks and objectives, and complement other City priorities.

As described in Chapter 2, it is critical that restoration actions be sequenced for maximum effectiveness (for example, hydrological and physical habitat conditions must be adequate before enhancements related specifically to water quality or biological communities can reasonably be expected to succeed). In this analysis, greater weight will be given to those elements of restoration that are most fundamental or likely to have the greatest overall impact. Other things being equal, projects that have more heavily weighted elements of restoration, such as restoring flow on a watershed scale, will be evaluated more favorably than other projects.

Table 3-5 shows the relative weightings of different elements of the overall restoration process and the corresponding restoration guideline.

TABLE 3-5
Relative Weightings of Restoration Elements, in Alignment with Restoration Guidelines

Relative Weighting	Restoration Element	Restoration Guideline
Higher/heavier	Protect existing areas of high-quality habitats or properly functioning watershed processes	3.1
↕	Protect, improve or reestablish connectivity of healthy habitat areas	3.2
	Control sources of degradation	3.3
Lower/lighter	Enhance (or restore if feasible) properly functioning: • watershed hydrologic conditions • physical habitat • water quality conditions • biological communities	3.4

Each potential action or project will be screened for (1) effectiveness in addressing problems, (2) ability to maintain conditions that are functioning properly, and (3) implementability, which encompasses technical feasibility and cost. A rough cost estimate may be generated at this point. A technical feasibility assessment can consider, for example, how effective the action is likely to be, whether methods for implementing the action are well understood or experimental, and whether the action would be likely to have community and agency support. This exercise will help distinguish projects that are clear "winners" from those that would offer relatively marginal overall performance or benefits. Projects that currently are clearly infeasible will likely be excluded from further consideration and analysis at the present time. (However, because watershed management is an iterative process, projects that are infeasible now but that have the potential for significant ecological benefit may be reconsidered at a later date, once circumstances and economies of scale have changed). Also, some projects may be excluded at this point because they clearly are financially infeasible or socially unacceptable.

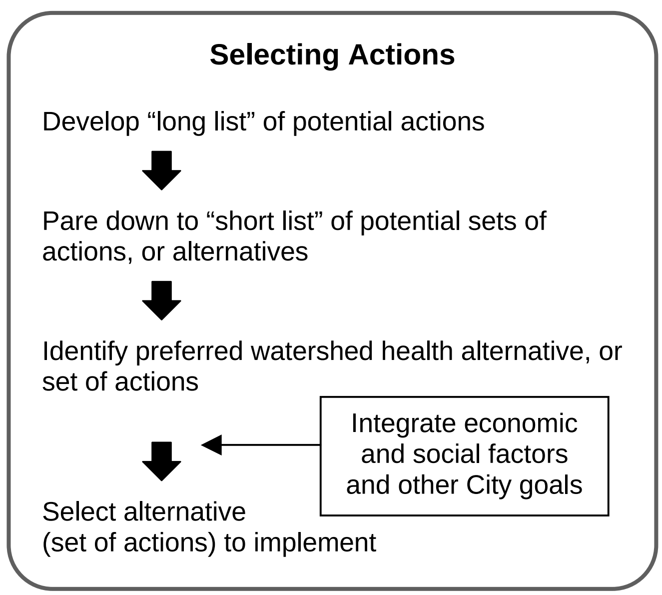
Projects that address multiple problems or protection/ restoration opportunities, or that affect several watershed processes at once, will likely make the "short list" of potential actions that will undergo further evaluation.

Actions or projects can be organized in several different ways, such as by overall watershed goal and objective, type of problem and solution, or location. In this way it may become apparent which actions should be considered together or are likely to have the greatest benefit. For example, in a stream reach with fine sediment problems, several individual erosion and sediment control actions might be grouped together to achieve the single goal of improving water quality. Or it could be that problems that all have a similar cause can be solved with a single action. An example of this would be high water temperatures and low levels of dissolved oxygen caused by a lack of riparian vegetation; both problems could be addressed by planting riparian vegetation. Actions that address more than one watershed process at once, thus offering multiple—and perhaps wide-ranging—benefits for the effort involved in implementing a single action, may be given higher priority than actions that address only one watershed process.

As always, in sorting potential actions or projects into logical groupings it will be important to consider the underlying processes or situations that are creating each problem, not just the symptoms of problems. Additional analysis and modeling (such as with the tools described in Appendix H) may occur at this point to help assess the potential effectiveness of actions or sets of actions in addressing problems or opportunities. The City expects to use a variety of analytical tools and models to help evaluate alternatives and actions. The appropriate use of models will be further defined in consultation with stakeholders and technical experts during the alternatives development process. The models used, the level of confidence associated with their use, and the basis for decisions about priority actions will be documented. Similarly, policy makers will be well informed about the limitations of the models selected.

The sequencing and grouping of potential actions and projects will allow the City to derive a "short list" of sets of actions grouped by goal, objective and/or alignment with the restoration guidelines in Chapter 2. These sets of actions will undergo final evaluation in Step 8, during which the preferred set of actions will be selected. In essence, each set of actions will be a different alternative, and only one alternative will be chosen for design and implementation.

The City cannot know in advance what the "short list" of alternatives will be for a given watershed. However, it is likely that as potential actions are identified, analyzed and grouped, certain general types of alternatives that best meet the goals, objectives and benchmarks will emerge. These alternatives could range from merely maintaining the status quo (this would involve implementing only those projects that are currently in progress and responding to land use changes that will result from population and development over the next several decades) to full protection and restoration of all ecological functions needed to support healthy, self-sustaining populations of salmonids. Intermediate-level alternatives might involve protecting existing water quality and habitat when this could be done cost-effectively; enhancing stream flow, hydrology, habitat and water quality throughout a watershed; or some combination of these options, such as merely protecting habitat in one reach but fully restoring stream flow in another.



Step 8: Select the Set of Actions to Be Implemented

Step 8 involves selecting the set of actions to be implemented. This will be achieved by analyzing the "short list" of action alternatives identified in Step 7 and selecting the most appropriate alternative considering both what is required to best achieve watershed health and what is practically achievable when other, nontechnical values are considered (such as social and economic considerations).

Selection of actions to be implemented would be relatively straightforward if the only considerations were cost and effectiveness in achieving watershed health objectives. In reality, however, it is never that simple. Societal values, for example, come into play, or it may be that the least expensive solution is not the best in terms of achieving watershed health objectives. Final selection of actions to be implemented, particularly those that require expenditures of public funds, that affect private landowners or that may be related to other City values, must be conducted.

Evaluating Alternatives. Evaluation of the "short list" of alternatives and recommending a preferred alternative may be accomplished by developing and applying a structured decision-making tool that assesses the relative merits of each alternative, using a set of evaluation factors and an objective scoring system. The selection may be facilitated by using a structured decision-making process (see Appendix H).

The evaluation factors will reflect City of Portland values with respect to watershed health and will be weighted according to the relative importance of each factor. For example, in accordance with the restoration guidelines in Chapter 2, the evaluation factor "Protects high-quality habitats" would likely be weighted more heavily than the evaluation factor "Reestablishes biological communities." Using this approach, alternatives would receive a score for each evaluation factor, and the total score for each alternative would provide a means of comparing the various alternatives.

Figure 3-4 shows a hypothetical example of factors that could be used to evaluate the various alternatives, with the evaluation factors arranged to point to possible relative weightings.

FIGURE 3-4
Hypothetical Example of Evaluation Factors and Their Relative Weightings for Use in Comparing Different Alternatives

Relative Weighting	Evaluation Factors: Biological	Evaluation Factors: Implementation
Higher	Protects high-quality habitats	Is technically effective, in terms of magnitude and duration
↕	Maximizes habitat access and connectivity	Has minimal implementation and maintenance costs
	Maximizes watershed functions: • hydrology • physical habitat • water quality • biological communities	Is accepted by regulators Does not conflict with other actions and projects
Lower		

This evaluation of alternatives will focus on watershed health values, along with key factors associated with the implementability of actions, such as technical effectiveness, cost and the likelihood of regulatory acceptance.

Simple, objective criteria can be established for each evaluation factor, to serve as the basis for scoring. These criteria will likely be both quantitative and qualitative. For example, quantitative criteria may be available to rate alternatives with respect to habitat access and availability, such as the number of acres of salmonid habitat that would be protected or enhanced. Qualitative criteria would be applied when quantitative criteria are not available, or to complement a quantitative measure, and would be in the form of index values (such as 1 to 5 or 1 to 10) or ratings (such as "excellent," "good," "fair," and "poor"), accompanied by clear narrative rationale. Both quantitative and qualitative criteria must identify the full range of potential project performance and collectively define the basis for the evaluation and prioritization of candidate sets of actions.

To facilitate the analysis of the alternatives, the City may use a structured decision-making tool such as a multi-attribute analysis. Such an analysis provides a systematic means of applying and tracking the rating of alternatives based on evaluation factors and criteria. Structured decision-making processes that use a multi-attribute analysis have many advantages, especially when the alternatives being considered reflect competing values, the relatively "easy" decisions have already been made and disparate benefits need to be compared.

Structured decision making is helpful when the "easy" decisions have already been made, the remaining alternatives reflect competing values, and disparate benefits need to be compared. Structured decision making clearly documents the decision-making process so that it is understandable to other City bureaus, policy makers and the public.

Identifying the Alternative That Best Achieves Watershed Health. The "short list" of alternatives will include an alternative that would best achieve watershed health objectives and benchmarks. This particular alternative will deal purely with watershed health needs related to technical elements (that is, stream flow, water quality, physical habitat and biological communities), apart from consideration of costs and other factors (such as social and economic considerations). Integration with those other nontechnical elements of City goals occurs later in this step. By first identifying the alternative that would best achieve watershed health, the City can clearly understand what it would take to truly achieve watershed and river health, even if important social and economic factors were not considered.

It is likely that selecting the preferred alternative will require additional analysis and modeling (such as with the tools described Appendix H) to help determine the relative effectiveness of different alternatives. The analysis will probably include a structured decision-making process as outlined below. Such a structured process would provide a rigorous and repeatable method for selecting a preferred alternative and would allow the basis for decisions to be clearly documented.

Considering and Incorporating Other City Values When Selecting Actions to Be Implemented. After identifying the alternative that would best achieve watershed health, but before final selection of actions that will be implemented, there is one very important additional analysis task: considering other City values and incorporating those values into the watershed management process. The steps taken to this point are intended to provide accurate, scientifically based information about possible watershed restoration actions. However, this final analysis task considers the selection of actions within a larger context of decision making at the City of

Depending on stakeholder concerns and the type and location of the actions being considered, other City of Portland values— such as economic viability or trans-portation—will be included in the evaluation prior to final selection of actions.

Portland—a context that includes public debate; consideration of social, economic and other goals, such as public health and safety, neighborhood livability and aesthetics; and policy decisions that reflect the City's ability to achieve watershed health in light of the actual costs of doing so.

The City is working to improve its ability to assign economic values to ecosystem services. These are quantifiable services that an ecosystem provides to people, including provisioning services, such as food and water; regulating services, such as flood control; cultural services, such as recreational and cultural benefits; and supporting services, such as habitat for fish and wildlife. Resource economists assign monetary values to these services to estimate the economic value of a healthy ecosystem.

For example, the City recently completed a case study to improve its ability to assign economic values to ecosystem services using a proposed flood mitigation and wetland enhancement project in the Lents neighborhood of Portland. This case study estimated the values of flood protection, bird and salmonid habitat, air pollution removal, water quality improvements, increased property values and recreational opportunities. Values assigned to ecosystem services in this case study provide a starting point for assigning economic worth to these services citywide, and the study serves as an informative demonstration of cost-benefit analysis. Appendix H presents additional information on available tools for ecosystem cost-benefit analysis, such as the Net Environmental Benefit Analysis, or NEBA.

For incorporating other City values in this final analysis, the City of Portland will investigate structured, multiple-objective methodologies[21] for possible use in assessing the potential success and desirability of preferred alternatives vis-à-vis other competing City goals and objectives. Such a tool would be designed to assist stakeholders and decision makers in understanding the socioeconomic and environmental impacts of various restoration options at both the local and watershed levels.

At this point, the preferred alternative will be selected and the actions that constitute that alternative will be incorporated into the watershed management plan for the watershed in question.

The City of Portland will prepare watershed management plans that lay out actions and projects, such as on-the-ground capital improvement projects, necessary to achieve watershed health. Additional plans and documents may also be needed to carry out recommended actions and comply with federal and state laws.

Completing the Watershed Management Plan and Related Documents. At the conclusion of Step 8, the City of Portland will complete—for each watershed—a watershed management plan and related documents that lay out actions and projects necessary to achieve watershed health goals, objectives and initial benchmarks.[22] These may include, for example, capital improvement projects, new or amended development codes, land acquisition, or incentive, education and stewardship programs that will be consistent with the watershed plans. Additional plans and documents will need to be developed for compliance with federal, state or regional regulations. These could include a water quality management plan, a

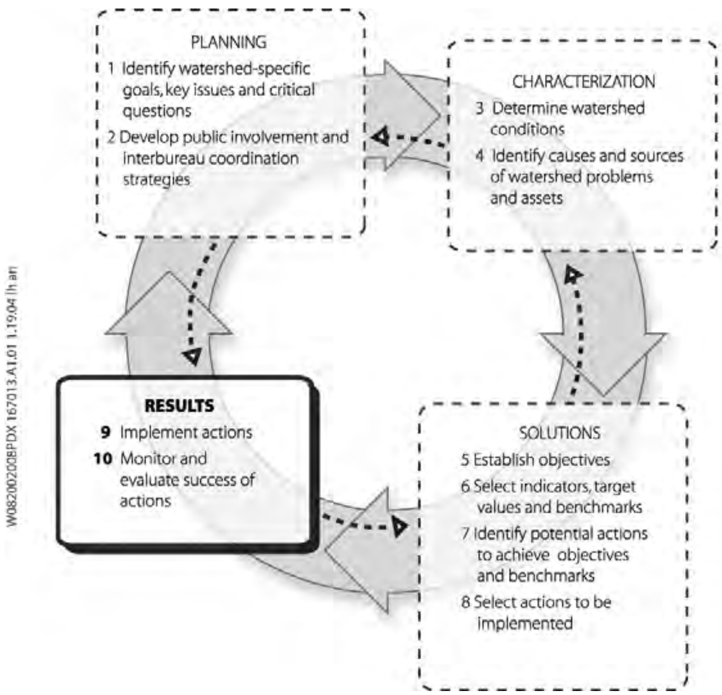
21 An example of such a methodology is the RESTORE Decision Support System (DSS) (Lamy and others 2002), which is being used for multi-objective decision making in several watersheds in the Willamette Basin and may be adaptable to meet the City's needs.

22 Because this process is iterative and takes place over time, additional sets of actions to achieve future benchmarks will be identified.

habitat conservation plan, refinements of the TMDL management plan for a given stream, modifications of the *Stormwater Management Manual* (City of Portland Bureau of Environmental Services 2000), and Comprehensive Plan amendments, for example. Adoption of these other plans, programs or compliance documents would be accomplished through processes separate from those used to develop the watershed management plans.

Results: Implementing and Monitoring Watershed Projects and Actions

In the last two steps of the watershed management process, the selected actions are implemented and monitored for success. The following section summarizes these steps, which can be described only broadly because the specific needs in the results stage depend heavily on the findings and outcomes of the characterization and solutions stages.



Step 9: Implement the Selected Set of Actions

Sequencing of Actions. The City of Portland will sequence implementation of actions and projects as recommended in Step 7 and selected in Step 8 of the watershed management process. Sequencing of actions and projects will be based on several factors:

- The severity of environmental problems, as indicated by magnitude, frequency, duration of occurrence, etc.
- The restoration guidelines presented in Chapter 2. These give preference to actions that, for example, protect existing functioning habitats, improve connectivity to these habitats and focus restoration actions on the processes that create and maintain watershed health.
- Implementability, which encompasses technical feasibility and cost. Technical feasibility includes how effective and durable the action is likely to be and whether the action has strong community and regulatory agency support.

- Regional considerations**.** This includes coordination with other jurisdictions to ensure effectiveness, minimize cost (perhaps), enhance restoration and recovery at the regional scale and anticipate any counteracting activities**.**
- Other City of Portland goals, plans and fiscal priorities.

Implementing the Selected Set of Actions. As an outcome of Step 8, the watershed management plans will call for implementation of a variety of voluntary and mandatory actions such as tree planting, habitat restoration, development of pollution reduction facilities and other capital improvement projects, as well as regulatory and nonregulatory programs. Various City of Portland bureaus and stakeholders will be involved in helping to plan, design, install, operate or maintain these actions or projects.

As noted earlier, the watershed management plans may also generate new plans and documents, such as a water quality management plan, a habitat conservation plan or Comprehensive Plan amendments, among others. Many of these will undergo their own public review or other institutional processes for adoption or approval**.**

Implementing actions involves leadership, communication and consensus building with stakeholders about the selected watershed actions and their purposes. It also involves administrative and technical tasks, such as ensuring that actions are implemented, projects are designed and installed properly, permits are obtained, funds are secured and spent appropriately, implementation proceeds on schedule, projects are maintained and public education is taking place.

Actions that involve land acquisition or that otherwise affect land use may be particularly complicated, and strong incentives may be needed to help implement such actions. For example, tax incentives, technical assistance, cost sharing and collaboration with other local governments and private enterprises can be useful in garnering support and assistance.

Step 10: Monitor and Evaluate the Success of Actions

Adaptive Management. Knowledge about watershed and ecological processes and the effects of urban development is imperfect, particularly with regard to the effects of urban development. Although ongoing research continually improves understanding of watershed and ecological processes and sensitivities, uncertainty remains. Adaptive management provides a process by which course corrections can be made as new knowledge is gained.

> **Implementing the preferred actions will test the assumptions and knowledge on which the watershed management process is based. As the effects of the actions are monitored and new knowledge is gained, the assumptions will be refined.**

This *Framework* explicitly describes the City of Portland's assumptions about ecological principles and the presumed relationships among several ecological indicators and watershed health. It also seeks to make clear how the City will evaluate the benefits and risks of specific actions and the technical basis upon which the City will make its watershed management decisions. Making these assumptions explicit allows those engaged in the management process, as well as interested stakeholders and regulatory agencies, to evaluate the City's assumptions and use them as a basis for further decision making. Explicit disclosure of assumptions enables those assumptions to be questioned and tested to ensure that they are reasonable and consistent with existing information.

The City cannot predict absolutely the effect an action will have on watershed health, so it is necessary to incorporate adaptive management into the implementation of watershed management plans. Where the effects of an action may not be predictable absolutely, adaptive management can be used to test important assumptions, reduce uncertainties and inform expectations and adaptive management decisions. Adaptive management ensures the flexibility and feedback needed to make sound decisions that will lead to achievement or appropriate revision of long-term watershed goals and objectives. Flexibility and feedback also are necessary so that decisions can be revisited in light of new information or unforeseen circumstances, and so that unsuccessful actions and unattainable objectives can be replaced with more realistic and durable ones.

Successful adaptive management requires several elements:

- Clear and measurable objectives
- An accurate and comprehensive characterization of existing conditions
- Benchmarks, or intermediate values with timelines, that define the rate at which objectives should be approached
- A comprehensive, well-designed monitoring program that includes the watershed indicators
- Regular review of monitoring results and a feedback mechanism by which actions can be adjusted if progress toward objectives and benchmarks is inadequate or if objectives and benchmarks need to be revised

If assumptions about ecological principles, indicators and watershed health are explicit, they can be evaluated and used as a basis for further decision making by the City, stakeholders and regulatory agencies.

The Importance of a Monitoring Program. Progress in meeting the benchmarks and ultimate objectives cannot be measured without a comprehensive monitoring program that addresses the major components of watershed health. The City of Portland currently conducts extensive monitoring that addresses many of these components (see Table 3-6 and Appendix C). The City also is reviewing existing monitoring efforts to improve the extent to which they monitor progress toward objectives. Each watershed management plan will further define the monitoring components and the appropriate spatial and temporal scale needed to adequately evaluate the degree to which watershed health meets objectives within the watershed.

Perhaps the most obvious and yet most neglected aspect of adaptive management is regular comparison of monitoring data with the benchmarks and objectives. This comparison is necessary to analyze the success of actions in meeting benchmarks and to change actions when progress toward objectives is unacceptable.

What is monitoring?

Monitoring is the process of measuring the chemical, physical or biological characteristics of various environmental indicators. Monitoring can be conducted in a variety of media, such as water, air, soil or sediments.

Part of the reason that this aspect is often underdeveloped within adaptive management programs is that it is difficult to develop—in advance—an objective feedback system that will adjust actions based on monitoring results. For example, it is difficult to define how close a monitoring result must be to a benchmark to be considered successful. Also, it is not possible to predict ahead of time all the ways in which an action could fail, or to determine alternative approaches that should be attempted, unless one has information on why the action might have failed or the benchmark was not met. Actions can fail for many reasons: there was a lack of follow-through or implementation, the causes of problems were not adequately understood, solutions were not appropriately designed to address the causes, inappropriate assumptions were made about the watershed or the effectiveness of a solution, the rate at which improvements in watershed health can occur were poorly understood, or actions (or inactions) of other entities affected the watershed in unanticipated ways. It may also be that confounding influences in other parts of the watershed negated the positive aspects of the action.

The City of Portland intends to use the following procedures to incorporate monitoring results into watershed actions, to improve their effectiveness in meeting objectives:

- Summarize monitoring data on a regular basis, compare these results to benchmarks, objectives and previous results and disseminate these results broadly to technical reviewers and stakeholders. Use these analyses to adjust actions, objectives or benchmarks appropriately.
- Periodically conduct workshops in which extensive analysis of monitoring results and their implications for the success of actions are discussed. Develop recommendations on how actions should be changed to better meet objectives.
- For components of watershed health that do not appear to be meeting their benchmarks or objectives, adjust actions by:
  - Reviewing information used to identify sources or causes of a problem, identifying uncertainties and data gaps in source identification, and collecting improved information where uncertainties or data gaps may have resulted in the application of inappropriate solutions.
  - Evaluating the design, assumptions and effectiveness of solutions. Use emerging research to improve or replace ineffective solutions.
  - Researching and updating the scientific foundation (Chapter 2), the indicators and the conceptual understanding of the watershed on which the indicators are founded (Appendix G).
  - Using emerging research and monitoring data to test and refine the models used to prioritize problems, identify sources and identify solutions (Appendix H).
  - Evaluating and revising the objectives over time to ensure that they reflect the best available science on the conditions required for watershed health. There may be cases where an objective is scientifically appropriate but unattainable because of practical constraints within a reach or watershed. In these situations the City of Portland may evaluate the objectives for that reach on a case-by-case basis to

determine whether the objectives should be adjusted to reflect practical constraints or whether future advances in restoration methodology may eventually ease these constraints.

Through this approach of setting clear and measurable benchmarks and objectives, continually evaluating conditions and using information on progress toward benchmarks and objectives to adjust actions, the City of Portland will apply emerging information and an evolving understanding of watersheds and restoration technologies to improve restoration approaches over time.

Types of Monitoring. Monitoring and evaluation are the foundation of adaptive management. The purpose of monitoring and evaluation is to guide watershed management toward actions that contribute to the achievement of objectives while managing risk. There are typically four essential types of monitoring:

- **Implementation monitoring** assesses whether activities or projects have been carried out as planned.
- **Effectiveness monitoring** determines the extent to which the completed actions are functional and working. Effectiveness monitoring requires that the conditions influencing performance be assessed and that actions or measures be implemented properly.
- **Compliance monitoring** is a type of effectiveness monitoring that determines whether specific performance standards are being met. The location, frequency and method of measurement may be specified as part of the performance standard.
- **Validation monitoring** measures the extent to which the implemented actions have been successful at achieving the benchmarks, objectives and ultimate goal (such as protecting, enhancing and restoring target aquatic and terrestrial species and biological communities to maintain biodiversity in Portland's watersheds).

The City of Portland will be monitoring environmental indicators developed for use in determining the City's progress in achieving its watershed health goals, objectives and benchmarks. These indicators will be particularly relevant for effectiveness and validation monitoring, which indicate whether implemented actions are working as expected and contributing to achievement of the City of Portland's goals. The City also will monitor implemented solutions to support implementation monitoring.

Monitoring and Evaluation Strategy. The City's strategy for monitoring and evaluation to facilitate adaptive management will consist of several elements:

- A data gathering strategy, including scales and protocols
- Monitoring locations
- Monitoring parameters and methods
- Data quality assurance and quality control
- Data collection
- Data analysis and evaluation
- Timetable, staff and funding requirements

Monitoring the effectiveness of implemented actions will ensure continual improvement in the conceptual understanding that underlies the watershed management process. This is an iterative process.

The monitoring projects needed for Step 10 of the watershed management process will not necessarily be stand-alone efforts; rather, the monitoring will build on existing monitoring programs that the City of Portland already is conducting as part of the management of its water, sewer and other resources and facilities. In some cases, monitoring data that will be needed for Step 10 are already being collected via current monitoring efforts. In other cases, needed monitoring data will be obtained by revising or augmenting existing monitoring activities. In some instances, new, independent monitoring projects may be needed.

Data analysis and evaluation needs will be an explicit element of data monitoring strategy and design for determining sampling parameters, methods, locations, frequencies, conditions, and so on. The City recognizes that natural variability is inherent in natural systems. In addition, the City's monitoring and evaluation strategy for characterization of existing conditions will strive to account for such variability, including analyzing results in statistical or probabilistic terms. Types of monitoring that the City of Portland currently conducts and that may be useful in Step 10 of the watershed management process are listed in Table 3-6. Future efforts may include (for example) monitoring of invasive plant species and native wildlife.

TABLE 3-6
Examples of Types of Monitoring (by Purpose) Being Conducted by the City of Portland

Type of Monitoring	Type of Monitoring
Treatment processes (influent or effluent monitoring)	Discharge monitoring
Compliance monitoring (TMDL, National Pollutant Discharge Elimination System [NPDES], ESA, others)	Maintenance-generated sediment quality analysis (from stormwater facilities and sumps)
Spill identification and tracking	Groundwater level and quality analysis
Waterways sediment risk evaluation	Public health and safety—bacteria at contact use sites
Water quality and quantity facility monitoring	Physical systems characterization (stream geomorphology, flow characteristics)
Assessments of operation and maintenance practices for water quality effectiveness	Precipitation and other metadata
Mixing zone analysis	Pollutant source identification (chronic)
Ambient water quality evaluation	Flow monitoring (in-system and surface water)
Stormwater quality associated with facilities	Tree canopy
	Fish presence

Ensuring That City Actions Are Compatible with Watershed Health Goals

The watershed management process described in this chapter will result in the creation of comprehensive watershed management plans and related documents for each of Portland's key urban-area watersheds and waterways: the lower Willamette River, the Columbia Slough and Johnson, Fanno and Tryon creeks.

The watershed management plans are designed to be the City's key resource for ensuring that programs and actions are compatible with watershed health goals.

The watershed management plans will present information about conditions in Portland's watersheds and the goals, objectives and benchmarks for watershed health; they also will identify restoration and protection actions that would improve watershed health.

In addition to laying out the actions that need to be taken, the watershed management plans will provide guidance and suggest changes in the way the City of Portland conducts various activities and projects that affect watershed health. The watershed management plans will be designed to be the City's key resource for ensuring, to the greatest degree possible, that programs and actions are compatible with watershed health goals.

Beyond Watershed Management Plans: Additional Guidance

Healthy watersheds will not be achieved and maintained simply by developing watershed management plans and implementing approved actions. The City of Portland must also consider the effects of programs, practices and projects that are not in and of themselves developed for, or focused on, achieving watershed health. These include transportation plans, capital improvement projects that are not a result of the watershed management planning process, the City of Portland's Comprehensive Plan and codes, urban renewal plans, land use reviews, permitting and enforcement, vegetation management and operations and maintenance. Because all of these activities have the potential to affect watershed and river health, they need to be compatible with the City's watershed health goals, objectives and benchmarks and approved watershed management plans and actions to the extent possible. The alternative is to make a deliberate, explicit and documented decision—in a public process—to act in a manner inconsistent with the watershed health goals and provide appropriate mitigation.

Because transportation plans, capital improvement projects, urban renewal, land use reviews and other City activities have the potential to affect watershed and river health, they, too, need to be compatible with the City's watershed and river health goals.

Guidance for City bureaus will be provided in many forms, such as technical guides and memoranda, day-to-day technical assistance, training sessions, workshops, policy manuals and budget adjustments. The City's Endangered Species Act Program will assist other bureaus in navigating the federal ESA permitting process and, together with the Bureau of Environmental Services (BES), can serve as a resource for the bureaus whose actions are most likely to affect watershed health. Appendix B describes the primary federal, state and regional laws related to watershed health and the City's obligations under those laws.

Technical memoranda, day-to-day technical assistance, training sessions, workshops and policy manuals will provide additional guidance to bureaus whose actions affect watershed health.

On a day-to-day-basis, there will be opportunities for interbureau collaboration in the early stages of projects. For example, BES can work with the Transportation Bureau to prioritize and apply for federal funding for road and bridge retrofit projects to capture stormwater runoff and can work with the Endangered Species Act Program to improve fish passage.

Identification of CIP Projects

Another ongoing effort that warrants special mention is capital improvement program (CIP) projects that have a high probability of affecting watersheds, rivers or biological communities. Identifying such CIP projects involves working closely with CIP committees across the City, to answer four questions:

- Does the CIP project involve any instream work in the Willamette, Tryon, Johnson, Lower Columbia Slough, Stephens, Balch, Saltzman or Miller Creek waterways? (Current or proposed ESA-listed species are known to occur in these areas.)
- Does the CIP project involve manipulation or disturbance of land or vegetation within 300 feet of any of the above waterways?
- Does the CIP project involve the discharge of any water or material into the above waterways, or diversion of any water or material out of the above waterways?
- Is there a risk that the CIP project could by accident involve instream work, the manipulation or disturbance of land or vegetation within 300 feet of the above waterways, the discharge of water or material into the above waterways or the diversion of water or material out of any of the above waterways?

CIP projects for which the answer to any of these questions is "yes" have the potential to require more formal consultations with the regulatory agencies (that is, the U.S. Army Corps of Engineers, NOAA Fisheries and the USFWS).

Compatibility Process for Major New and Ongoing Projects

Because the City of Portland is a dynamic, ever-changing place, new City projects, plans and actions periodically will be proposed and implemented while the initial watershed management plans are being developed and after they are approved. If new projects are proposed before the watershed-specific objectives, benchmarks and plans are approved, those projects will need to be planned, designed and implemented in a manner that is consistent with the scientific principles, restoration guidelines and watershed health goals in the *Framework*. Projects that are proposed after the watershed management plans are approved will need to be consistent with watershed-specific objectives and other aspects of the watershed management plans. It is not enough to plan a project, only to find out late in the process that the project is inconsistent with an approved watershed management plan, or that it must be redesigned to obtain a state or federal permit. Nor is it enough for a project merely to state its intention to be consistent with watershed goals. Rather, it is necessary to have a process that ensures, or institutionalizes, consistency with watershed health goals to the greatest degree possible.

Such a process is presented below. Adapted from the basic watershed management steps described in this chapter, it can be applied by any bureau, program or project team on specific, major[23] new projects at the City of Portland to ensure that the projects are consistent with the City's goals for watershed and river health. The steps are as follows:

From the start, new City projects must be planned so that they are consistent with the City's goals for watershed health.

[23] The City of Portland will define "major" by identifying criteria that would trigger required participation in this process. Criteria could include, for example, habitat restoration projects of a certain size; projects that must use "scientifically based" approaches to planning, management, decision making or implementation; and projects that have the potential to affect water quality, water quantity, instream habitat, listed salmonid species, biological communities or other watershed health parameters.

- Review the watershed management plans to determine which watershed health goals, objectives and benchmarks are applicable to the project.
- Determine how the project can help achieve watershed health goals, objectives and benchmarks. Incorporate appropriate project goals related to watershed health.
- Include in the scope of work a work plan for the project that includes coordination with applicable watershed management plans (or other relevant projects and plans) at key points, such as the issuance of Requests for Proposals and public involvement planning. Look for opportunities to share data, combine efforts, reduce potential conflicts and maximize efficiencies. Coordinate as early as possible with the Natural Resources Team regarding local, state and federal permits.
- Make use of existing information about conditions within the project area, especially information that has been gathered via the characterization phase of the watershed process.
- When designing the new project, incorporate relevant policies and recommendations specified in the watershed management plans, to the extent possible. Ensure that project elements are compatible with (and certainly not inconsistent with) approved watershed management plans.
- Use modeling tools (see Appendix H) and other quantitative and qualitative methods to determine the probable positive and negative effects the new project will have on watershed health (as expressed in objectives and benchmarks for selected indicators).
- Redesign or adjust the new project as necessary to help achieve the benchmarks for selected indicators, or select alternatives that best help achieve those benchmarks.
- Monitor the implementation of the project to determine how successful it is in achieving its watershed-related goals and objectives and how compatible it is with the City of Portland's watershed and river health goals. Coordinate monitoring efforts with those of the natural resource bureaus that are responsible for watershed management.
- Apply adaptive management throughout the life of the project.

To facilitate the planning of major new projects so that they are compatible with watershed health, the City's natural resources staff will provide training and develop documents that can guide City bureaus and offices through this process. Such training and guidance documents will specify the responsibilities of each bureau and office, provide reference materials and procedural checklists and list City staff who can serve as resources.

Program Assessment: Compatibility of All City Programs with Watershed Health Goals

The City of Portland should establish a process for periodically evaluating its programs, plans, practices and projects to ensure—to the greatest degree possible—that (1) existing and future City of Portland programs, plans, projects and practices do not adversely affect watershed health, and (2) that they are consistent with approved watershed management plans and watershed health goals, objectives and benchmarks. This process would involve the following:

- Identifying City bureaus and offices whose activities have the potential to affect watershed health, both positively and negatively. In general, these are the bureaus that are represented on the River Renaissance Management Team**:** Planning, Development Services, Water, Transportation, Parks, Environmental Services, Fire, Office of Sustainability and the Portland Development Commission. This list is based on an initial evaluation performed by Beak Consultants Incorporated in 1998 (*Assessment of City of Portland Activities for Potential to Affect Steelhead*) and will need to be updated as City activities change over the years.
- Identifying bureaus and offices that have specific programs, plans, practices and/or projects that could affect watershed health through policy adoption, funding and/or implementation. Again, the Beak report (Beak Consultants Incorporated 1998) provides an initial assessment that for some bureaus and offices may be a starting point for this task.
- Evaluating those bureaus' and offices' programs, plans, practices and/or projects in terms of the following and presenting the information to the City Council for endorsement and consideration of funding requests:
  - Purpose and authorization.
  - Key activities.
  - Potential beneficial and negative impacts to watershed health.
  - Relationship to City watershed health goals as established in watershed management plans and the City's Comprehensive Plan.
  - Methods to avoid, reduce or mitigate potential adverse impacts. These methods could include adjusting the bureau's mission, programs or procedures or implementing new rules and codes.
  - Methods to identify opportunities to enhance watershed health through the identified programs, plans, etc.
  - Funding and other resources required to avoid, reduce or mitigate potential adverse impacts and to enhance watershed health.
- Reporting the results of this periodic program assessment to the City Council on a regular basis, coinciding with budgeting efforts.

If necessary, the City's natural resources staff will provide technical assistance to the identified bureaus and offices in completing the process of determining whether their activities are compatible with the City of Portland's watershed health goals.

The above process is not intended to be onerous or rigid. Rather, it is a way of periodically checking to see whether City bureaus and programs are—overall, and on balance—applying the principles of watershed management to both their everyday activities and their long-range programs. If not, City bureaus can then make adjustments in their operations to enhance watershed health.

CHAPTER 4

Ongoing Elements of Watershed Management

As explained in Chapter 1, the citizens and government of Portland have a vision for the City that involves a thriving natural river system with clean, healthy urban waterways and uplands. Such a system would benefit fish, wildlife, plant communities, and—by enhancing Portland's livability, environmental health and economic vitality—people, too.

Applying the scientific principles and guidelines in the *Framework* and following the watershed process it describes will necessitate many more ongoing efforts.

Although the *Framework for Integrated Management of Watershed Health* represents an important step in making this vision a reality, applying the scientific principles and guidelines in the *Framework* and following the watershed process it describes is iterative and will necessitate many more ongoing efforts. For the *Framework* approach to be successful over the coming decades, the City will need to address existing uncertainties about species and conditions in the City's watersheds, and the extent to which watershed and habitat conditions can be protected or restored in the urban environment. The City also will need to develop more detailed guidance on implementing the technical steps and tools described in the *Framework*, develop a monitoring program to track progress, provide appropriate funding, involve stakeholders and the public in the *Framework* processes, and provide regional coordination and leadership on issues related to watershed health. In addition, the City will need to have communitywide discussions regarding the broad-scale implications of the *Framework*, to determine how urban growth and development in Portland and the metropolitan area can best occur while the City strives to achieve its watershed health goals and meet its statutory obligations.

Addressing Uncertainties

The City of Portland has a great deal of information about its watersheds, but it does not have all the information it needs about current conditions, the species that use its watersheds and how certain aspects of the ecosystem function, especially in an urban setting. If the *Framework* approach is to be effective, these data gaps will need to be filled through surveys, studies and monitoring, as well as by reviewing the most current scientific literature.

At a species level, the City of Portland should monitor the distribution of salmonids and their seasonal use of habitat in the City's watersheds; continue ongoing research on juvenile salmonid use of banks and near-shore areas in the lower Willamette River; evaluate how hatchery programs are affecting the City's ability to reach its goals; and study the distribution and habitat use of key riparian and terrestrial wildlife species. At the ecosystem level, data gaps to be filled include identifying how particular elements of the urban ecosystem contribute to the system's healthy functioning (such as the role of tributaries, riparian areas and floodplains in large, low-gradient river systems), how conditions in the

City's upland areas affect watershed health, and the extent to which urban watersheds can achieve the "normative" structure and function of healthy, well-functioning ecosystems.

Delineating Elements of the *Framework*

The *Framework* presents a general outline of the steps the City of Portland intends to follow to improve the health of its watersheds, rather than detailed "how-to" instructions. Consequently, certain elements of the *Framework* will need to be delineated in more detail before the *Framework* can be implemented fully. This will involve clarifying roles and responsibilities for *Framework*-related activities; refining models and other analytical tools; establishing protocols for storing, managing and sharing accumulated data, both within the City and externally; developing specific criteria and processes for evaluating and selecting actions; identifying techniques for applying adaptive management; and providing guidance and training on the *Framework* to City staff.

Developing Monitoring Programs

The City already conducts certain monitoring activities that may be useful in the *Framework's* watershed management process (see Table 3-6). However, the City will need to develop a coordinated, integrated monitoring program that can be used specifically for adaptive watershed management, as described in Chapter 3. This monitoring program should specify protocols and methodologies; include the hydrology, water quality, physical habitat and biological community indicators that are selected for each watershed; build on existing monitoring activities as much as possible; and be consistent with regional monitoring and evaluation efforts. The City also should assign monitoring responsibilities among bureaus and develop mechanisms for using monitoring data in decision making.

Providing Appropriate Funding

Funds will need to be allocated to City bureaus that are leading the effort to develop watershed management plans, as well as to others who must implement, monitor and evaluate the results of selected actions. Funding will also be needed to ensure proper operation and maintenance of projects, and to ensure meaningful public involvement. In addition, City bureaus that are planning major new projects will need funding to assist those projects in undergoing the compatibility process described in Chapter 3. This will ensure that new projects are completed in a manner that is consistent with the City's goals for watershed health.

Involving Stakeholders and Others

Because the success of any public project rests in part on involving the public, it will be necessary for the City to effectively communicate watershed health information to multiple stakeholders and engage them in both policy-level and project-level decisions. Information on current watershed conditions, the City's approach to watershed management and implications for the future all will be important parts of an open dialogue on watershed health in Portland. The City also will need to garner public, agency and stakeholder support for its watershed-related efforts.

To ensure the ongoing scientific soundness of the City's watershed health activities, the City has established a science advisory group that can be called upon to advise the City on technical issues and review watershed-related documents the City generates. From time to time, there may be documents that should be reviewed by a team of independent scientists, much the way the Independent Science Team provided an independent peer review of this *Framework* document.

Providing Regional Coordination and Leadership

Because Portland's watersheds exist within the context of a large, ecologically connected region, the City cannot achieve all of its goals for healthy watersheds by acting unilaterally. In other words, what happens in Portland's watersheds is affected by the decisions of other jurisdictions and agencies in the Willamette and Columbia basins. For the *Framework* to be successful, the City must continue to build relationships with other entities in the region and—to the extent possible—influence those entities' decisions such that they support watershed health throughout the region. The City also must coordinate with Metro, and with federal and state agencies to ensure that its watershed management approach is in step with work being done by them. Lastly, forging strong public and private partnerships at the local and state levels will help build support for achieving healthy watersheds and foster coordinated action at a variety of scales.

Addressing the Tough Issues

Applying the processes in the *Framework* will bring to light accurate, scientifically sound information regarding what is needed, from an ecological standpoint, to achieve healthy watersheds. However, it is likely that this information also will raise fundamental questions about Portland's future and how competing demands on limited resources within the City will be addressed.

For example, it is reasonable to expect that issues will arise such as how to do the following:

- Reconcile the demand for riverside industrial and residential land with efforts to comply with regional, state and federal laws that require improved habitat in the lower Willamette.
- Protect off-channel and shallow water habitat while respecting the public's desire for recreational opportunities.
- Preserve the autonomy of private landowners while encouraging actions on private property that enhance watershed health.
- Maintain the City's ability to provide services in the face of a growing population, without jeopardizing important ecological functions that, once lost, may never be regained.

- Take a long-term view when calculating the true costs and benefits of watershed management activities.
- Guide new development such that it improves rather than degrades watershed conditions.
- Share the responsibility for improving watershed conditions in the context of a growing population. For example, to what degree should the City rely on infrastructure, such as CSO abatement facilities, to solve watershed problems? To what degree (and how) should the City address new and existing development to moderate its ecological impact?

In addressing these and other implications of the *Framework*, the City should seek solutions that integrate seemingly competing values and provide the best possible outcome for as many parties involved as possible. This will entail engaging the public in constructive dialogue about how urban growth and development in Portland and the metropolitan area can best occur while still allowing the City to achieve its watershed health goals and meet its regulatory obligations.

APPENDIX A

River Renaissance Visions and Strategies

APPENDIX A

River Renaissance Visions and Strategies

The Portland City Council endorsed the following River Renaissance visions and strategies on March 21, 2001:

Assure a Clean and Healthy River for Fish, Wildlife, and People

- Acknowledge that the Willamette River is part of a connected ecosystem that includes a system of natural functions integral to maintaining the health of the River. Work with communities and government agencies throughout the watershed to advance and coordinate watershed protection, restoration and cleanup actions that are critical to ensuring a functioning urban ecosystem. Manage watershed health and urban uses in a manner that is mutually supportive.
- Improve water quality in the river and tributaries through innovative stormwater management and control of sewage flows to the river.
- Advance Superfund clean-up activities to remove or isolate pollutants in Portland Harbor and at their source.
- Encourage environmentally-friendly building techniques and designs to use resources efficiently and minimize adverse impacts.
- Do our part to recover wild native salmon populations in the river and its tributaries.
- Restore and protect streamside habitat and floodplain areas. Plant native vegetation and control invasive species along waterways and throughout the watershed. Plan, restore, and maintain the Willamette River Greenway for fish, wildlife, and people.
- Improve habitat conditions in Johnson, Tryon, and Fanno Creeks, the Columbia Slough, and the smaller westside streams.
- Advance our scientific knowledge of clean and healthy river systems and their restoration in an urban environment.
- Restore Ross Island as a natural area in the center of our city.

Maintain and Enhance Our Prosperous Working Harbor

- Promote Portland as a hub for ship, barge, railroad, highway, and air transportation and as a Pacific Northwest gateway to the changing global marketplace.
- Provide efficient and economical freight movement for the region's industries and commerce.
- Invest in the harbor's industrial districts—a cornerstone of our regional economy.
- Explore and adopt new technologies, designs, and industrial practices that support habitat restoration and the improvement of water quality.

- Expand public awareness of the importance of the harbor and industrial waterfront in relation to the regional and state economy.
- Integrate regional freight-transportation and industrial objectives into river protection and enhancement activities.
- Use the Portland Harbor Superfund listing as an opportunity to create new partnerships and environmental clean-up industries and technologies.
- Promote Portland as a leader in sustainable business.
- Consider the needs of, and impacts on, the working harbor as we plan for river protection and enhancement.

Embrace the River as Portland's Front Yard

- Draw on the river as a place to reconnect with our history and the soul of our city.
- Acquire lands for new and expanded parks and natural areas. Assemble an open space system that focuses on, and radiates from, the river.
- Create opportunities for access to the water's edge, for boating, fishing, swimming, and other river recreation activities.
- Complete the Willamette River Greenway Trail and the 40 Mile Loop Trail to provide a continuous interconnected recreation and transportation corridor along both sides of the river.
- Connect new and existing neighborhoods to and across the river, through rails, trails, bikeways, streets, view corridors, and water-based transit systems.
- Build a world-class monument in a prominent riverfront location.
- Improve river access opportunities for motorized and non-motorized watercraft.
- Provide safe and convenient pedestrian and bicycle access to trails and roads and across bridges.

Create Vibrant Waterfront Districts and Neighborhoods

- As redevelopment occurs along the river, establish a prominent greenway with public spaces and natural places. Orient new development toward the river, and infuse buildings and neighborhoods with inspired architecture.
- Strengthen the Central City by focusing on the river as a unifying feature.
- Reconfigure the I-5 Freeway to bring together both sides of the Central City and to revitalize the eastside waterfront.
- Create new commercial and residential areas.
- Dedicate more of the waterfront to museums, cultural institutions, outdoor learning venues, Native American history, public art, and the interpretation of history and natural science.

- Establish festivals, regattas, and sporting events to build awareness of and celebrate the river.
- Provide a diversity of housing opportunities adjacent to the river and a range of riverfront experiences.
- Strengthen the regional and waterfront economy through efforts that enhance waterfront livability and environmental health.

Promote Partnerships, Leadership, and Education

- Assemble the River Renaissance Partners, a group of government, tribal, business, neighborhood, and environmental leaders to advocate for implementation of the Vision.
- Establish a multi-jurisdictional organization responsible for managing local river improvement efforts and coordinating with upstream and downstream communities.
- Inspire long-term commitment through successful early actions.
- Educate and involve our diverse community to promote stewardship of the river.
- Involve the schools and draw upon the energy, thoughts, and dreams of our future leaders.
- Recognize that neither the public sector nor private enterprise can implement the Vision alone. Foster collaboration between public and private entities.
- Work with community groups to build awareness for River Renaissance values.
- Establish a foundation or similar organization to help fund the implementation of River Renaissance.
- Emphasize strategies to share costs for salmon recovery and other river enhancements.
- Work with private property owners to leverage private investments.

APPENDIX B

Regulations Protecting Watershed and River Health

APPENDIX B

Regulations Protecting Watershed and River Health

More than 150 years of development and human activity in and around Portland have degraded water quality and habitat in the Willamette River, its tributaries and its watersheds. Alterations of stream and river flows, increases in impervious area, and degradation and loss of habitat have occurred in much of the urban area. Populations of steelhead trout and Chinook, coho and chum salmon that use Portland's waterways currently are listed as threatened under the federal Endangered Species Act (ESA).

In 2000, a six-mile stretch of the Lower Willamette River—the Portland Harbor—was listed as a federal Superfund site because of contamination in sediments discovered in a joint U.S. Environmental Protection Agency (EPA)/Oregon Department of Environmental Quality (DEQ) study. This makes the Portland Harbor subject to cleanup as required by the Comprehensive Environmental Response, Compensation and Liability Act, or CERCLA. Furthermore, water quality standards for water temperature, bacteria and toxics, including mercury, often are not met in the Willamette River. Therefore, as required under the federal Clean Water Act (CWA), DEQ is preparing total maximum daily load (TMDL) and water quality management plan (WQMP) documents for the Willamette River Basin, including the lower Willamette River and tributaries in the Portland area, for submittal to EPA in early 2006.

A fundamental purpose of the watershed management process in the *Framework* is to ensure a coordinated, systematic approach to achieving the City's watershed health goals.

The ESA, CERCLA and CWA are only some of the environmental laws and regulations pertaining to water quality and management with which the City of Portland must comply. Others include the Safe Drinking Water Act (SDWA), which affects how the City manages its sumps and stormwater wells; Oregon's statewide land use goals, which guide streamside and other development throughout the City; and Title 3 of Metro's *Urban Growth Management Functional Plan*, which requires the City to meet performance standards for protecting streams, rivers, wetlands and floodplains.

By improving overall watershed health, the City can improve habitat for ESA-listed fish, control stream temperatures and pollutant loadings, reduce the impact of development and protect wetlands. All of these help the City meet its various legal obligations in an integrated way.

These separate laws and regulations each have their own requirements and stipulations that affect a host of City programs and activities, and they have given rise to specific City programs and projects concerned with compliance. The watershed management process presented in the *Framework* document is an opportunity to coordinate and integrate some of these efforts to address the City's obligations under federal, state and regional laws and regulations. By focusing on improving overall watershed health, as described in the *Framework*, the City can expect to alter the physical structure of waterways for the benefit of threatened fish, help control temperatures and pollutant loadings in streams, reduce the impact of development on natural resources and protect existing wetlands, all of which help the City meet its various obligations in an integrated way.

This appendix summarizes the key federal, state and regional regulations pertaining to watershed health and the obligations that the City has under those statues. Federal regulations—the ESA, CWA, SDWA and CERCLA—are addressed first, followed by state and regional regulations.

Federal Regulations

The City of Portland is required to comply with the ESA, CWA, SDWA and CERCLA—key federal statutes and regulations aimed at protecting watershed and river health. Failures to comply can lead to restrictions on business operations, increased costs for cleanup and penalties, detrimental impacts to the environment and other problems. A fundamental purpose of the *Framework* is to present a process that provides for coordination and integration of City actions aimed at compliance with the ESA, CWA, SDWA and CERCLA.

Improving watershed and river health will go a long way toward satisfying multiple federal requirements.

Some of these actions are already occurring: the City is taking a proactive leadership role in the Portland Harbor cleanup efforts and is implementing a massive public works project to remove stormwater from the combined sewer system and control combined sewer overflows. With respect to the ESA, the City is committed to going beyond avoidance of a "take"[1] of a listed species by contributing to recovery of the listed species. Recently, issuance of a permit for underground injection control under the Safe Drinking Water Act, the first of its kind in the country for municipalities, has added the dimension of groundwater protection to the range of integrated elements of overall watershed health. A coordinated, systematic approach that improves overall watershed and river health will be the most efficient and effective way of both addressing multiple regulatory requirements and achieving citywide goals and objectives. The process described in this *Framework* is designed to enable the City to achieve its watershed health goals in the most scientifically sound, cost-effective way.

Coordination and integration of the City's compliance efforts make sense because of the important technical and policy links among these regulations. For example, the CWA and ESA share an important and significant technical link in ensuring that water quality is adequate to protect cold water biota, including ESA-listed salmonid species (such as steelhead, Chinook and chum salmon).[2] Similarly, the City's program to comply with state

[1] "Take" is defined as to "harm, harass, kill, injure, or modify essential breeding, feeding, and sheltering behavior" (per ESA Section 9 (a)(1) "take" prohibitions).

[2] Many of Oregon's state water quality standards are derived from water quality criteria developed from research on salmonids. Oregon's standards also already require that water quality conditions protect species listed under the ESA. For instance, the Willamette River's designated beneficial uses include anadromous fish passage, salmonid fish rearing, salmonid fish spawning, resident fish and aquatic life and fishing (Oregon Administrative Rule [OAR] 340-041-0042).

land use planning and Metro requirements limits development that affects streams and riparian areas that are needed to protect these cold water biota.

Each of the key statutes or regulations applies to a certain geographic area, all of which are encompassed by the watershed management plans that will be generated via the watershed management process presented in Chapter 3. Thus, the watershed management process has the potential to coordinate and integrate various compliance activities, in essence targeting multiple regulations with a single process—or a single action, project or group of projects that are fully coordinated.

Federal Regulatory Coordination and Integration

The federal statutes and regulations discussed in this chapter—ESA, CWA, SDWA and CERCLA—apply to many important City of Portland programs and activities, from land use and watershed planning to road construction and wastewater management. The relationships between the statutes and various City programs or activities are shown in Table B-1. The fact that a single environmental statute can apply directly or indirectly to so many City programs, and that individual programs or activities are governed by multiple federal statutes, points to the value of the coordination and integration of City efforts to comply with these regulations.

Regulatory coordination and integration are roles that the *Framework* intends to guide, by presenting a watershed management process that incorporates considerations—and generates solutions—related to all the key federal regulations.

By coordinating and integrating actions aimed at achieving watershed health, the City of Portland expects the following benefits:

- A proactive rather than reactive approach to achieving compliance with regulations aimed at protecting watershed and river health
- More timely, efficient and effective responses to regulatory requirements
- A more comprehensive, watershed-based approach to meeting the mandates of the regulations
- Improved coordination with various agencies responsible for implementing and enforcing the regulations
- Better linkages to regional processes
- Improved accountability for results

For efficiency, the watershed management process involves identifying relevant regulatory requirements and permitting processes and then "packaging" multiple restoration activities for consultation with—and permitting by—the regulatory agencies.

In addition, the City of Portland expects that an integrated approach will allow improved coordination with various agencies responsible for implementing and enforcing federal regulations. For example, as alternatives are evaluated and selected to fulfill watershed and river health objectives (as described in Chapter 3), the City will identify the regulatory requirements and permitting processes for implementing the associated actions, which then can be organized and grouped according to possible linkages among these regulatory processes. In so doing, the City envisions that an important outcome of the *Framework* process may be a "packaging" of City actions for consultation with, and permitting by, the regulatory agencies.

TABLE B-1
Matrix of Major City Programs or Activities and Relevant Federal Regulations

Program or Activity	Environmental Statutes			
	ESA	CWA	CERCLA	SDWA
Development Standards and Codes	●	●	○	●
Development Reviews and Approvals	●	●	○	●
Land Use Planning	●	●	○	●
Land Conservation	●	●	○	○
Watershed Planning	●	●	●	●
Water Treatment and Delivery	○	●	○	●
Stormwater Management	●	●	●	●
Sanitary Wastewater Management	●	●	●	○
Solid Waste Management	○	○	●	○
Road/Bridge Construction and Maintenance	●	●	○	○
Building Construction and Maintenance	●	●	○	●
Environmental Enhancement Activities	●	●	○	○
Park, Natural Area and Landscape Activities	●	●	○	○

● = Program directly assists in meeting regulatory requirements.
○ = Program indirectly assists in meeting regulatory requirements depending on the details of the program or activity.
ESA = Endangered Species Act
CWA = Clean Water Act
SDWA = Safe Drinking Water Act
CERCLA = Comprehensive Environmental Response, Compensation and Liability Act

A systematic, coordinated, integrated way of managing watersheds, such as the process presented in Chapter 3, is critical because it provides a means of identifying those actions that will improve watershed and river health most efficiently. And, as previously discussed, improved watershed and river health will go a long way toward satisfying federal requirements and meeting the City's own goals for a clean and healthy river, and Portland's livability and economic vitality.

The coordination and integration of compliance activities is an important outcome of the watershed management process, which is designed to identify the most efficient way for the City to improve watershed health.

The key federal statutes and regulations and their implications for Portland are discussed below.

Federal Endangered Species Act

Key Salmon and Steelhead Listings

In November 1991, Snake River sockeye salmon (*Oncorhynchus nerka*) became the first salmon listed by the National Marine Fisheries Service in the National Oceanic and Atmospheric Administration (NOAA Fisheries) under the federal ESA[3]. In 2000 the Oregon Department of Fish and Wildlife listed Lower Columbia River coho as endangered under the state's Endangered Species Act. By March 1999, NOAA Fisheries issued final rules to list 25 additional populations, called "evolutionarily significant units" (ESUs), of Pacific salmon and steelhead. In addition, in March 1999 the U.S. Fish and Wildlife Service (USFWS) proposed the Southwest Washington/Columbia River ESU of coastal cutthroat trout (*O. clarki*) for listing as threatened under the federal ESA. The USFWS decided not to list this cutthroat ESU, but the Service announced its intent to conduct a status review of the species and that review may result in a federal listing. In June 2005, NOAA Fisheries designated the Lower Columbia River coho salmon *(O. kisutch)* as threatened. And, in the spring of 2003, Pacific and brook lamprey were petitioned for listing under the federal ESA. The U.S. Fish and Wildlife Service denied the petition. However, litigation over the agency's decision is pending.

In February 2002, NOAA Fisheries announced that it would reconsider its ESA listing determinations for the 27 ESUs of Pacific salmon and steelhead in light of court decisions (67 Code of Federal Regulations [CFR] 6215). In May 2004, NOAA Fisheries announced the release of new proposed listing determinations for the 27 ESUs. These include 13 ESUs of steelhead and salmon that may use or migrate through watercourses in the Portland area (Table B-2). Ten of these 13 ESUs were proposed for listing as threatened: the upper Willamette River, lower Columbia River, Snake River fall-run and Snake River spring/summer-run Chinook salmon (*O. tshawytscha*); the upper Willamette River, lower Columbia River, middle Columbia River and Snake River basin steelhead (*O. mykiss*); the lower Columbia River coho salmon (*O. kisutch*); and the Columbia River chum salmon (*O. keta*). Three of the 13 ESUs are proposed for listing as endangered: the upper Columbia River spring-run Chinook salmon (*O. tshawytscha*), upper Columbia River steelhead (*O. mykiss*), and Snake River sockeye salmon (*O. nerka*). NOAA Fisheries published its final listing designations during June 2005. The current ESA listing status for the 13 ESUs of salmon and steelhead found in the Portland area are summarized in Table B-2.

[3] The State of Oregon has listed some salmonids under the state Endangered Species Act. However, that law applies only to actions of state agencies on state-owned or state-leased lands.

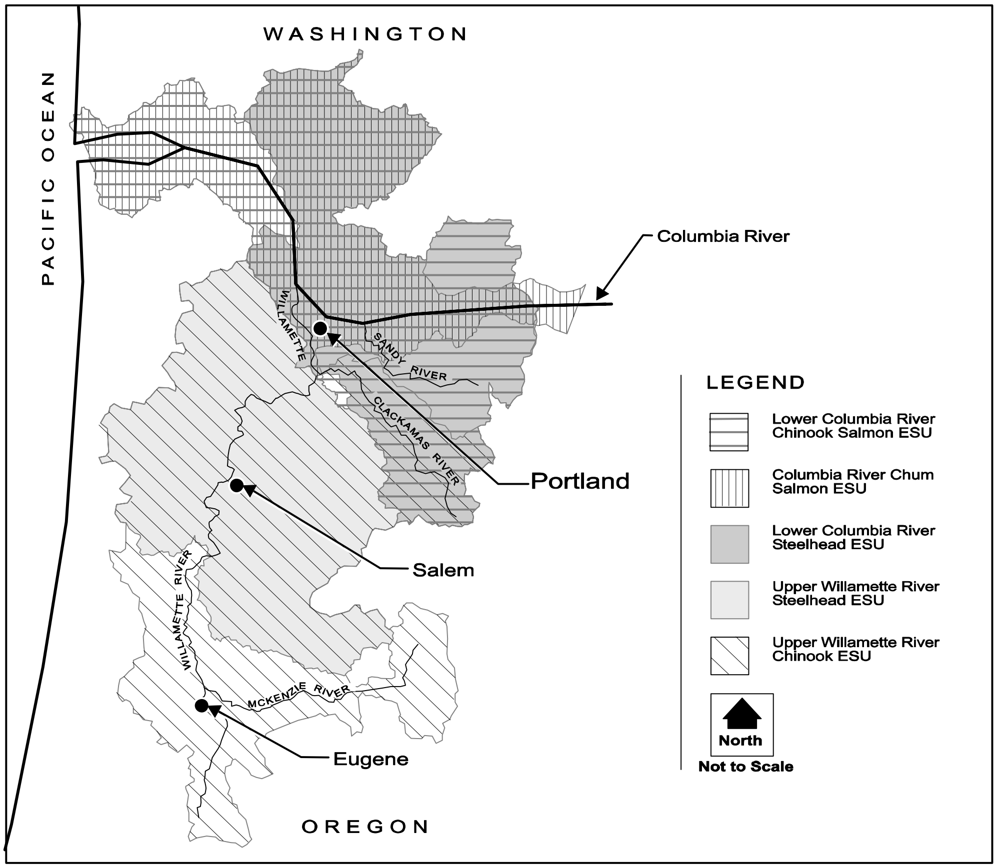
TABLE B-2
ESA Status of Key Salmonid Species Found in the Vicinity of the City of Portland

Species	Scientific Name	ESU	Current (March 1999) ESA Listing Status	Proposed (March 2005) ESA Listing Status
Steelhead trout	*Oncorhynchus mykiss*	Lower Columbia River	Threatened	Threatened
Steelhead trout	*Oncorhynchus mykiss*	Middle Columbia River	Threatened	Threatened
Steelhead trout	*Oncorhynchus mykiss*	Upper Columbia River	Endangered	Endangered
Steelhead trout	*Oncorhynchus mykiss*	Upper Willamette River	Threatened	Threatened
Steelhead trout	*Oncorhynchus mykiss*	Snake River	Threatened	Threatened
Chinook salmon	*Oncorhynchus tshawytscha*	Lower Columbia River	Threatened	Threatened
Chinook salmon	*Oncorhynchus tshawytscha*	Upper Columbia Spring-run	Endangered	Endangered
Chinook salmon	*Oncorhynchus tshawytscha*	Upper Willamette River	Threatened	Threatened
Chinook salmon	*Oncorhynchus tshawytscha*	Snake River Spring/summer-run	Threatened	Threatened
Chinook salmon	*Oncorhynchus tshawytscha*	Snake River Fall-run	Threatened	Threatened
Chum salmon	*Oncorhynchus keta*	Columbia River	Threatened	Threatened
Coho salmon	*Oncorhynchus kisutch*	Lower Columbia River/Southwest Washington	Threatened	Threatened
Sockeye salmon	*Oncorhynchus nerka*	Snake River	Endangered	Endangered

As shown in Figure B-1, Portland's watersheds and waterways are within six of these 13 salmonid ESUs. The salmonids from these six ESUs use various watercourses in the Portland area, including the Columbia River, Columbia Slough, Willamette River, Johnson Creek, Tryon Creek, Fanno Creek and several other smaller westside streams. The other seven ESUs include salmon and steelhead that migrate past Portland on the way to and from ESU areas in the upper and middle Columbia River and Snake River.

Maps showing the distribution of salmon and steelhead in Portland's watersheds and waterways are shown in Appendix E, "The City's Natural Environment " (see Figures E-2 and E-3).

FIGURE B-1
Portland-Area Salmonid ESUs Listed Under the Federal ESA



Source: Adapted from 1999 NOAA Fisheries information.

The listing of these ESUs prompted the City of Portland to take proactive steps toward the protection and ultimate recovery of these species. Adding urgency to the City of Portland's actions is the fact that NOAA Fisheries enacted regulations under Section 4(d) of the ESA to apply the "take" prohibitions contained in Section 9(a) of the ESA to these ESUs. These prohibitions make it unlawful to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect the listed species, or even to attempt to engage in such conduct. For the purposes of the ESA, NOAA Fisheries has defined "harm" to include habitat modification if the modification kills or injures fish by significantly impairing essential behavioral patterns such as feeding, sheltering, rearing, migrating, breeding and spawning (per ESA Section 9(a)(1) "take" prohibitions).

City Response to Federal Listings

Following the listing of the Lower Columbia ESU of steelhead in March 1998, the City of Portland began developing a comprehensive, citywide response to the listing. Agreement among the City Council on the following four-pronged approach to responding to the listing was achieved on May 23, 1998, and the Council adopted the approach on July 22 of that year (Resolution No. 35715):

- Involve all City of Portland bureaus, to maximize effectiveness and efficiency.
- Collaborate with NOAA Fisheries to prepare a program that not only complies with the requirements of the ESA but also assists in salmonid recovery.
- Because the listed fish species use watersheds that cross political boundaries, integrate the City of Portland's response with regional and state responses, to the extent possible.
- Enlist the help of the citizenry at a number of levels in developing the response to the listing.

The *Framework* and the watershed management process are the most efficient and effective way of achieving directives of the City Council and getting at the root of watershed problems.

The City's Endangered Species Act Program [4]was charged with coordinating the City's response to listings under the federal ESA. The City's response is basically twofold. It involves both ESA compliance (meaning avoiding "take" of a listed species) and assisting with recovery of listed salmonids. This is a choice the City has made to go beyond simply avoiding "take" of listed species.

ESA Compliance. The City of Portland has a variety of options to ensure ESA compliance:

- Avoiding "take" altogether
- Adhering to Section 4(d) rules
- Obtaining incidental "take" authorization under Section 7
- Obtaining an incidental "take" permit under Section 10
- Assisting with recovery

Avoiding "Take" Altogether. Avoiding "take" altogether is the clearest and most direct way of meeting the ESA's fundamental objective of protecting and conserving listed species. For example, the City may determine that certain activities do not cause "take" for various reasons, such as that no species or suitable habitat is present in areas affected by the activity or that no link exists between the activity and a species or habitat effect. The City is free to plan and conduct activities that avoid "take" altogether, without needing to have an ESA consultation or agreement with the federal government.

The City's Endangered Species Act Program plays a key role in seeing that City actions do not result in an unlawful "take" of a listed species, by doing the following:

- – Evaluating City of Portland activities, programs and practices for their potential to affect fish and wildlife and their habitats
- – Identifying and prioritizing City of Portland activities, programs and projects for Endangered Species Act Program attention, assessment and guidance (with the assistance of other bureaus and programs)
- – Providing technical support to all bureaus regarding individual proposed projects that involve ESA-related activities

[4] The City's Endangered Species Act Program is part of the Bureau of Environmental Service's Science, Fish and Wildlife Division within the Watershed Services Group.

– Providing oversight for activities that involve federal permitting, funding or oversight that will involve NOAA Fisheries or USFWS under Section 7

– Reviewing draft requests for proposals to hire consultants to address ESA-related issues

– Communicating criteria and processes to City of Portland bureaus and programs to address ESA-related issues

– Monitoring the implementation of projects and actions taken to ensure that City activities, programs and projects comply with permit conditions, avoid or minimize "take", and assist in recovery of species

– Ensuring that watershed management plans are adequate to address ESA obligations

This *Framework* and the watershed management process that it presents (see Chapter 3) are, in part, efforts to ensure that City of Portland actions do not result in an unlawful "take" of a listed species. The *Framework* and watershed management process also will help the City of Portland determine which of the other federal ESA compliance options, discussed below, will make sense for the City over the long term.

Adhering to Section 4(d) Rules. Section 4(d) of the ESA authorizes NOAA Fisheries or the USFWS to issue special rules that regulate "take" of threatened species. The rules can provide exceptions from the "take" prohibition for incidental "take" of threatened species if specific City programs provide for the conservation of those species or promote their overall recovery. In July 2000, NOAA Fisheries issued special 4(d) rules for the steelhead and Chinook salmon ESUs in Table B-2. These rules allow specific lawful activities that otherwise would be considered incidental or direct "take". Examples of activities allowed under the 4(d) rules include certain restoration activities and properly screened water diversion devices. There also is an approved 4(d) limit for Portland Parks Bureau's Integrated Pest Management (IPM) Program, which manages vegetation through mechanical treatment, the use of herbicides and other means. The 4(d) protection granted to the IPM Program requires annual reporting, which includes testing of water quality.

The City also has an approved 4(d) limitation for the its routine road maintenance activities. The current effort requires the City to review its practices and conduct its road maintenance activities in accordance with the Oregon Department of Transportation's (ODOT) *Routine Road Maintenance Water Quality and Habitat Guide* with appropriate additions and changes to reflect Portland's unique characteristics (June 1999). Other efforts under way include seeking approval of the City's *Stormwater Management Manual* (City of Portland Bureau of Environmental Services 2004) under the 4(d) Section 12 limit.

The City's ESA Program has received a 4(d) limit for ongoing scientific research for the past several years. The limit allows the City to conduct regular surveys of its waterbodies, including specific sites where future capital improvement projects are planned. The overall goal of the research efforts is to build baseline information on fish use in all of the waterbodies. Over time the City will be able to document changes in fish use as restoration efforts are undertaken, as well conservation measures taken by the City bureaus to minimize or eliminate the effects of their action throughout the watersheds. In addition, the information will be used for Section 7 consultations and preparation of biological assessments.

Obtaining Incidental "Take" Authorization under Section 7. Section 7 of the federal ESA applies when a project must obtain federal approval or federal funding, such as roadway improvement projects that use Federal Highway Administration (FHWA) funds. If a federal agency permits, authorizes or funds a certain City activity, the agency must consult with NOAA Fisheries and USFWS to ensure that the action taken by the federal agency on the activity does not jeopardize a listed species or detrimentally affect critical habitat. Obtaining Section 7 incidental "take" authorization usually involves preparing a biological assessment and consulting with NOAA Fisheries and/or USFWS, which then issues a biological opinion and incidental "take" statement.

In October 2002, the City entered into a federal ESA Section 7 streamlining agreement with NOAA Fisheries, the U.S. Army Corps of Engineers and USFWS. This agreement establishes a cooperative process for streamlining ESA Section 7 consultations among the four parties to the agreement. Streamlined consultations will provide a number of benefits, including increased coordination of the review, analysis and documentation of City projects, programs and activities, so that they proceed in a timely manner. The agreement is one of the first of its kind involving a municipality and federal agencies.

Through the streamlining agreement, efforts will be made to provide for coordination among the City and federal agencies early in the planning process for projects, programs and activities that require or would benefit from federal agency review. It is expected that such early consultation will result in the identification of potential impacts to listed species and critical habitat and the means to address such impacts. Early cooperation also is expected to speed the conservation of listed species while at the same time minimizing delay of proposed City projects, programs and activities.

The City and federal agencies have convened a team made up of their employees to meet on a quarterly basis to work toward the following:

- Expediting Section 7 consultations by batching similar projects or projects with similar timing needs, combining multiple agency consultations, etc.
- Development of information, documentation, formats and timeframes for biological evaluations/assessments (BE/BA) and biological opinions
- Agreement on the use of the programmatic biological opinion for Standard Local Operating Procedures for Endangered Species (SLOPES) for certain activities requiring U.S. Army Corps of Engineers permits in Oregon
- Development of additional compliance strategies in addition to Section 7 (for example, 4(d) rule limit and programmatic opportunities) as needed for City projects, programs and activities
- Better coordination of strategies to comply with the ESA and additional regulatory requirements with other state and federal regulatory programs

Obtaining an Incidental "Take" Permit under Section 10. Section 10 of the ESA allows NOAA Fisheries and USFWS to permit the incidental "take" of listed species by private parties and nonfederal jurisdictions as long as the "take" is incidental to otherwise lawful activities. In order to obtain an incidental "take" permit (ITP) under Section 10, a habitat conservation plan (HCP) must be prepared. An HCP details, among other things, the activities that will be covered by the ITP, the impacts that are likely to result from the incidental "take" and the mitigation measures that will be implemented. An implementation agreement that spells out the terms and conditions associated with the HCP and ITP also must be prepared. In addition, NOAA Fisheries and USFWS must comply with the National Environmental Policy Act (NEPA) by issuing an environmental assessment or environmental impact statement.

Improving overall watershed health will move watersheds closer to recovery than would merely aiming to comply with federal regulations.

Assisting with Recovery. Although the City Council did not specifically define "assisting with recovery" of listed species in Resolution 35715 (July 1998), the phrase clearly indicates more than simply avoiding "take" of listed species. The watershed management process described in the *Framework* provides the basis for both defining and achieving the City Council's directive.

Federal Clean Water Act

The federal Water Pollution Control Act Amendments of 1972 and subsequent amendments, now known as the Clean Water Act, regulate discharges of pollutants to waters of the United States from both point sources (such as discharges from pipes) and nonpoint sources (such as stormwater runoff).[5] The CWA calls for the "restoration and maintenance of the chemical, physical and biological integrity of the Nation's water." The CWA also states the intent, "where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water."

The City of Portland has responsibilities related to four sections of the CWA:

- Permits for stormwater and wastewater discharges as required under the National Pollutant Discharge Elimination System (NPDES) permitting program (Section 402 of the CWA)
- Water quality management planning to comply with established water quality standards and TMDL programs, which specify the maximum amounts of certain pollutants that a particular body of water is allowed to receive from all sources (Section 303 of the CWA)
- Permits for sediment removal and fill in waterways, such as construction activities in streams, wetlands and floodways (Section 404 of the CWA)

[5] Point sources are confined and discrete conveyances, such as a pipe, tunnel or conduit from which effluents containing pollutants are discharged. CWA compliance standards for point source discharges are usually in the form of specific numeric effluent limitations. Nonpoint sources are more diffuse, unconfined pollutant discharges without a specific discharge point. CWA compliance standards for nonpoint source discharges are usually in the form of best management practices (BMPs) that are implemented to be effective to the "maximum extent practicable" (MEP).

- Water quality certifications (Section 401 of the CWA) to demonstrate compliance with water quality standards for federal actions, such as U.S. Army Corps of Engineers removal/fill permits (Section 404 of the CWA)

These primary obligations under the CWA are described below.

CWA Section 402: NPDES Stormwater Program

The National Pollutant Discharge Elimination System permitting program was developed to control the discharge of point and certain nonpoint sources of pollution to the nation's waters. Although federally mandated, the NPDES program is administered in Oregon by DEQ. Under Section 402 of the CWA, the City of Portland has regulatory obligations for general municipal stormwater and treated municipal wastewater discharges from the Columbia Boulevard Wastewater Treatment Plant (WWTP) and Tryon Creek WWTP.

Requirements. In response to the 1987 amendments to the CWA, which included regulation of stormwater discharges under the NPDES permitting program, EPA developed Phase I of the NPDES Stormwater Program in 1990. This phase addressed sources of stormwater runoff that had the greatest potential to adversely affect water quality. Under Phase I, EPA required NPDES permit coverage for stormwater discharges from either of the following:

- "Medium" and "large" municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more
- Eleven categories of industrial activity, one of which includes stormwater runoff at treatment facility sites

Because the City of Portland falls into both of these categories, it has an MS4 stormwater permit for stormwater generated throughout the City and NPDES general industrial permits for stormwater discharges at each of its two WWTP facilities. The permits are issued and administered by DEQ, which administers both municipal and industrial NPDES permits and is responsible for enforcing NPDES regulations statewide.

The MS4 NPDES stormwater permit is the primary regulatory vehicle for management of stormwater quantity and quality (40 Code of Federal Regulations [CFR] 122.26(d)). Although the permit requirements apply only to areas where the sewer and stormwater conveyance systems are separate, the City Council has agreed with the City's Stormwater Advisory Committee's recommendation that minimum requirements be exceeded and that stormwater best management practices (BMPs) be implemented throughout Portland. The City has developed and maintains a comprehensive stormwater management program that addresses the following management practices:

- Development standards
- Industrial/commercial controls
- Illicit discharge controls
- Structural controls
- Operations and maintenance requirements
- Preservation and restoration of natural areas
- Public education and outreach

CWA Section 402: NPDES Wastewater Program

Under Section 402 of the CWA, point source discharges of pollutants into waters of the United States are regulated under the NPDES program.

The City of Portland has NPDES discharge permits for its municipal wastewater treatment facilities, the Columbia Boulevard and Tryon Creek WWTPs. The permits, which regulate the discharge of total suspended solids (TSS), biochemical oxygen demand (BOD) and *E. coli* to the Columbia and Willamette rivers, specify both technology-based and water quality-based effluent limits. Technology-based effluent limits are based on the technology available to control the pollutants, while water quality-based effluent limits specify numerical criteria that discharges must meet.

CWA Section 402: NPDES Stormwater Permits for Construction Projects

Under Section 402 of the CWA, stormwater permits for construction projects are required for any projects larger than one acre. They are required for City of Portland construction activities such as those undertaken as part of the combined sewer overflow (CSO) program, as well as public construction activities that discharge to the City's system.

CWA Section 303: TMDL Program

Section 303 established the water quality standards and total maximum daily load programs, which specify the maximum amounts of certain pollutants that a particular body of water is allowed to receive from all sources. Waters with pollutant levels above this maximum amount are considered water quality limited. The aim of the TMDL program is to manage water resources so that parameters or attributes that limit water quality in a specific stream reach (such as temperature, total suspended solids and pesticides) do not exceed standards and so that "beneficial uses" (such as recreation, cold water fisheries, municipal and industrial water supply and navigation) are attained and maintained. Beneficial uses are determined by the state and differ by water body and reach. Although federally mandated, the TMDL program is administered in Oregon by DEQ, which develops TMDLs on a basinwide level. EPA must approve the TMDLs developed by DEQ, and it consults with USFWS or NOAA Fisheries before doing so. TMDL allocations are typically implemented through NPDES permits for point source discharges and through water quality management plans for nonpoint sources.

Under Section 303(d) of the CWA, states are required to develop lists of impaired waters that do not meet water quality standards set by the state. DEQ places waterbodies that are "water quality limited" for certain parameters on its 303(d) list; this means that the waterbodies do not meet state-designated standards for such parameters as temperature, dissolved oxygen, bacteria, metals, pesticides and other pollutants. Oregon administrative rules generally prohibit new or increased discharges of the specified parameters to the listed waterbodies. In the Portland area, every river and stream except Balch Creek is water quality limited.

After a waterbody is placed on the 303(d) list, DEQ is required to develop TMDLs for the listed parameter(s). A TMDL provides the following:

- Specifications for the maximum amount of the pollutant that a waterbody can receive from all point and nonpoint sources and still meet water quality standards

- Allocations of pollutant loadings among point and nonpoint sources
- A Water Quality Management Plan that specifies the agencies and individuals responsible for implementing the TMDLs and the timelines for implementation.

Once TMDLs have been established for a stream or other body of water, the affected jurisdictions must develop implementation plans to achieve the identified requirements. Table B-3 shows the status of TMDL and load allocation development for waterways in the Portland area.

CWA Section 404: Removal/Fill Permits

CWA Section 404 establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Activities regulated under this program include placing fill or excavating in a wetland; building in a wetland; construction of boat ramps; construction of dams, dikes or bridges; stream channelization; and stream diversion. CWA Section 404 removal/fill permits are jointly administered by the U.S. Army Corps of Engineers and the Oregon Division of State Lands. The City of Portland occasionally obtains Section 404 removal/fill permits for projects associated with removal and fill activities in waterways, such as construction or restoration activities in streams, wetlands and floodways.

As described below, a Section 401 certification is typically required from DEQ. If threatened or endangered species may be affected by the proposed activity, the U.S. Army Corps of Engineers will consult with the appropriate federal agency (NOAA Fisheries or USFWS) to obtain a biological opinion on the effects to the species (as required under ESA Section 7). If the proposed activity will have significant impacts on the human environment, an environmental impact statement is required by the U.S. Army Corps of Engineers.

CWA Section 401: Water Quality Certifications

CWA Section 401 water quality certifications are administered by DEQ. These certify compliance with state water quality standards for a variety of federal actions with which the City of Portland might be involved. The major federal licenses and permits subject to Section 401 are Section 402 and 404 permits, Federal Energy Regulatory Commission (FERC) hydropower licenses and Rivers and Harbors Act Section 9 and 10 permits. DEQ makes its decisions to deny, certify or add conditions to permits or licenses primarily by ensuring that the activity will comply with state water quality standards. The Section 404 Corps permit is by far the most common federal permit issued that requires 401 certification. Examples of activities that may require a Section 404 permit and Section 401 water quality certification include placing fill or excavating in a wetland; building in a wetland; construction of boat ramps; construction of dams, dikes or bridges; stream channelization; and stream diversion.

ESA and CWA Procedural Links

The CWA shares some important procedural links with the ESA. The most prominent example is Section 404 permits issued by the U.S. Army Corps of Engineers, which are required to undergo an ESA Section 7 consultation if the action to be permitted may affect ESA-listed species. The process must ensure that the action is not likely to jeopardize listed species or adversely modify critical habitat.

In Oregon, EPA has delegated authority for administering many CWA permits to DEQ. The issuance of CWA permits by DEQ is not a federal action, and thus DEQ is not required to consult with NOAA Fisheries and USFWS before issuing a permit. However, EPA must now consult with NOAA Fisheries and USFWS under Section 7 of the ESA on EPA's approval of Oregon's water quality standards and state NPDES programs. NOAA Fisheries and USFWS recently developed a memorandum of agreement (MOA) with EPA to enhance interagency coordination of the ESA on NPDES programs and development of water quality standards (see 64 *Federal Register* 2742, January 15, 1999).

TABLE B-3
TMDL and Load Allocation Development for Water Quality-Limited Waterways in and around Portland

Waterway on the 303(d) List	Parameter(s)	TMDL and Load Allocation Established by DEQ?
Columbia Slough	Phosphorus Chlorophyll *a* pH Dissolved oxygen Bacteria Lead Dieldrin DDT/DDE Dioxin PCBs	Yes
Columbia Slough	Temperature	Under development (completion projected in early 2006)
Willamette River mainstem	Bacteria Mercury Temperature	Under development (completion projected in early 2006)
Fanno Creek	Chlorophyll *a*/phosphorus Dissolved oxygen Temperature Bacteria	Yes
All Willamette River tributaries	Mercury	Under development (completion projected in early 2006)
Johnson Creek	Temperature Bacteria DDT Dieldrin	Under development (completion projected in early 2006)
Tryon Creek	Temperature	Under development (completion projected in early 2006)
PCBs = polychlorinated biphenyls.		

The MOA seeks to enhance the efficiency and effectiveness of these consultations by providing specific procedures for coordination and prompt resolution of issues that may arise. Of particular interest is the fact that the MOA describes the Section 7 consultation process, noting that EPA must ensure that its actions are not likely to jeopardize listed species or adversely modify critical habitat. The MOA states that, "since NPDES permits are established to achieve water quality standards, they will account for point source effects [on listed species] insofar as water quality is concerned" (*Federal Register* 2001). Formal consultation would occur only if adverse effects were found to be likely, following preparation of a biological evaluation.

The MOA outlines a procedure in which ESA compliance would be reviewed only after DEQ issues a draft NPDES permit. At that point, EPA would make sure that USFWS and NOAA Fisheries were notified of the draft permit and that they would provide DEQ with information on species and habitats of concern. EPA would coordinate with NOAA Fisheries, USFWS and DEQ to ensure that ESA requirements are met. If they are not, EPA would exercise its right to deny the permit.

Oregon's state water quality standards already require that water quality conditions protect species listed under the ESA. For instance, the Columbia River is designated for all beneficial uses, including anadromous fish passage, salmonid fish rearing, salmonid fish spawning, resident fish and aquatic life and fishing (Oregon Administrative Rule [OAR] 340-041-0042, Table 6). In addition, narrative standards have been adopted that are specific to protection of sensitive aquatic life (see, for example, OAR 340-41-445(2)(i)(p)). Given such designated beneficial uses and narrative standards, DEQ can issue an NPDES permit or 401 certification only upon ensuring that the authorized action will not harm the listed species in the river, regardless of ESA requirements. Thus, DEQ may still end up relying on NOAA Fisheries, USFWS and the Oregon Department of Fish and Wildlife, even though DEQ does not formally engage in a Section 7 consultation process.

Although Oregon's state water quality standards require that water quality be adequate to protect listed species, NOAA Fisheries and USFWS have indicated that certain of the state's standards may not be adequate. For example, in July 1999, NOAA Fisheries issued a biological opinion on EPA's review of Oregon's standards for temperature, dissolved oxygen and pH and concluded that application of these standards could adversely affect certain life stages of listed anadromous salmonid species. A key outcome of these consultations is that NOAA Fisheries and USFWS worked with EPA, DEQ and other affected states on a regional temperature criteria development project to develop regional temperature criteria that will meet the biological requirements of listed salmonids for survival and recovery. As a result of those discussions, DEQ reissued its temperature water quality standards for the State of Oregon in December 2003 with final approval from EPA coming in March 2004. In December of 2005 those standards again came under legal challenge from third parties.

Safe Drinking Water Act

The SDWA (42 USC § 300f *et seq.*) created a comprehensive national framework designed to ensure the quality and safety of drinking water supplies. The main focus of the SDWA is on ensuring the quality of drinking water at the time it reaches consumers, rather than ensuring the (pretreatment) quality of the source supply. In Oregon, the SDWA involves some provisions for groundwater source protection. These provisions include prohibitions and management standards for underground injection control (UIC) wells, which include sumps, French drains and stormwater disposal wells. The City of Portland has conducted an inventory and evaluation of its UICs, particularly stormwater wells, and consulted with DEQ about permitting and registration options for the wells. The SDWA is not considered a primary regulatory driver for the assessment of watershed health as outlined in this *Framework*, but it may have indirect significance to the degree that groundwater source protection provisions benefit the quantity and quality of groundwater that discharges to the City's surface waterways. Protection of groundwater recharge, and encouraging natural hydrology in watersheds, involves the use of infiltrating methods of stormwater management. A key linkage to meeting other regulatory requirements is inclusion of best management practices using infiltration.

CERCLA

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, commonly known as Superfund) was enacted by Congress in 1980 and amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986. CERCLA provides broad federal authority to respond to releases or threatened releases of hazardous substances that may endanger public health or the environment. The act authorizes two kinds of response actions:

- Short-term removals where a prompt response is required
- Long-term remedial actions to permanently and significantly reduce dangers that are serious but not immediately life threatening

Portland Harbor NPL Listing

In 2000, EPA added the Portland Harbor site to its National Priorities List (NPL) for investigation and cleanup to be addressed under CERCLA. Elevated levels of polychlorinated biphenyls (PCBs), heavy metals, polycyclic aromatic hydrocarbons (PAHs), pesticides such as DDT and other contaminants are present in some sediments along a six-mile stretch of the lower Willamette River, from the southern tip of Sauvie Island (about 3.5 miles upstream from the mouth of the Columbia River) to Swan Island (about 9.2 miles upstream from the Columbia).

In September 2001, EPA completed negotiations that culminated in an "Administrative Order On Consent" with the Lower Willamette Group, a coalition of businesses and public agencies—including the City of Portland—that have voluntarily agreed to fund and participate in the investigation and cleanup of the site. This legal agreement designates DEQ as the lead agency for upland work along the banks of the river (where many of the historical contamination sources are located) and EPA as the lead agency for the in-water work on contaminated sediments. It also establishes guidance for conducting a remedial investigation and feasibility study (RI/FS), which will determine the nature and extent of contamination; and potential risks to humans, fish and wildlife.

The ultimate boundaries of the site will be determined at the conclusion of the RI/FS, when EPA documents the findings of the RI/FS in a Record of Decision and selects a preferred cleanup alternative.

Natural Resources Damage Assessment

In addition to the activities to evaluate contamination and implement cleanup, CERCLA also grants authority for federal and state agencies and tribal governments to act as Natural Resource Trustees and conduct a natural resources damage assessment (NRDA) at a Superfund site. The purpose of the NRDA process is to determine the extent of injuries to natural resources such as fish and wildlife as a result of the release of hazardous substances at the site since 1980, the date CERCLA was enacted; continuing damages from pollutants released prior to 1980 also are covered by CERCLA. The trustees can recover damages from the parties who have caused the injury, as well as mandate restoration actions as mitigation for those damages. These damage assessments and mitigation actions are paid by the parties responsible for releasing the hazardous substances and are in addition to those needed for site cleanup under CERCLA.

CERCLA Activities

DEQ is working on the cleanup of approximately 70 upland sites along the banks of the Willamette River. The work ranges from early stages of investigation to cleanup activities and includes identifying and controlling sources of harbor sediment contamination. Identified sources of contamination include numerous former and current operations, such as hazardous waste and petroleum product storage; marine construction (including World War II Liberty Ships); oil gasification operations; wood treating and pulp and paper production; agricultural chemical production; chlorine production; ship loading, maintenance, painting and repair; rail car manufacturing; and stormwater discharges. The City of Portland is working closely with DEQ to determine if the City stormwater outfalls within the Superfund site are conveying contamination to the river.

The *Framework* provide a process for identifying the highest priority projects to serve as early restoration projects—essentially, those projects that will provide the most important biological benefits. The *Framework* also will help ensure that actions taken to comply with the ESA and CWA do not conflict with CERCLA-related actions, and vice versa. For example, the watershed management process presented in Chapter 3 will help identify natural resource protection and restoration opportunities that will assist the City of Portland in meeting various regulatory requirements and will clearly describe which project would address which requirement.

Key State, Regional and Local Regulations

Oregon/EPA Performance Partnership Agreement (PPA) and Performance Partnership Grant (PPG)

In 2004, DEQ entered into a two-year Performance Partnership Agreement (PPA) with EPA Region 10 that promotes joint strategic planning and priority-setting processes for environmental protection in the state and supports the use of innovative strategies to solve environmental problems. PPAs are intended to strengthen protection of the environment by focusing attention on specific environmental goals and actual results, rather than government programs and the number of actions they take.

For the first time, much of the work DEQ is performing under the PPA is funded by an EPA Performance Partnership Grant (PPG), which combines several grants into a single, flexible grant package, thus streamlining grant administration and increasing DEQ's ability to shift resources to the highest environmental priorities. Grants related to the Clean Air Act, CWA, RCRA, Safe Drinking Water Act and Pollution Prevention Act have been incorporated into the Oregon/EPA PPG.

The Oregon/EPA PPA has components related to air quality, hazardous waste and water quality, including TMDL implementation in the Willamette River, permitting of the City of Portland's UIC wells, ongoing work in the Columbia River to reduce temperature and toxics, and a pilot project to prevent potential recontamination of Portland Harbor sediments via urban stormwater runoff. Also noteworthy in the context of this *Framework* document is DEQ's gradual shift to an integrated, cross-media, watershed-based approach to resolving environmental problems. This effort, which began in 2003, eventually will involve collaboration and coordination by multiple media offices (land, air and water) to develop and implement comprehensive watershed plans that could, for example, include TMDL development and implementation, cleanup of contaminated sites, removal of underground storage tanks, protection of groundwater, and minimization of airborne pollution within a single basin or subbasin. As of this writing, air quality and land quality had yet to be incorporated into the watershed-based approach but DEQ envisioned implementing the watershed approach in five basins, including the Willamette, by the conclusion of the PPA in 2006.

Oregon's Statewide Planning Goals and Guidelines

Since 1973, Oregon has maintained a strong statewide program for land use planning. The foundation of that program is a set of 19 statewide planning goals that express the state's policies on land use and related topics, such as citizen involvement, housing and natural resources. Most of the goals are accompanied by guidelines, which are suggestions about how a goal may be applied. As noted in Goal 2, guidelines are not mandatory.

Oregon's statewide goals are achieved through local comprehensive planning. State law requires each city and county to adopt a comprehensive plan and the zoning and land-division ordinances needed to put the plan into effect. The local comprehensive plans must be consistent with the statewide planning goals. Plans are reviewed for such consistency by the state's Land Conservation and Development Commission (LCDC). When LCDC officially approves a local government's plan, the plan is said to be "acknowledged." It then becomes the controlling document for land use in the area covered by that plan.

Following is a summary of the 19 statewide planning goals. Of these, Goals 5, 6, 7 and 15 relate directly to natural resources in Portland, and several other goals have ties or potential implications to watershed management planning and actions by the City. The 19 statewide planning goals are as follows:

- ***Goal 1: Citizen Involvement***. Goal 1 calls for "the opportunity for citizens to be involved in all phases of the planning process." It requires each city and county to have a citizen involvement program with six components specified in the goal. It also requires local governments to have a committee for citizen involvement (CCI) to monitor and encourage public participation in planning.

- ***Goal 2: Land Use Planning.*** Goal 2 outlines the basic procedures of Oregon's statewide planning program. It states that land use decisions are to be made in accordance with a comprehensive plan, and that suitable "implementation ordinances" to put the plan's policies into effect must be adopted. It requires that plans be based on "factual information"; that local plans and ordinances be coordinated with those of other jurisdictions and agencies; and that plans be reviewed periodically and amended as needed.
- ***Goal 3: Agricultural Lands.*** Goal 3 defines agricultural lands. It then requires counties to inventory such lands and to "preserve and maintain" them through exclusive farm use (EFU) zoning (per Oregon Revised Statute [ORS] Chapter 215).
- ***Goal 4: Forest Lands*.** This goal defines forest lands and requires counties to inventory them and adopt policies and ordinances that will "conserve forest lands for forest uses."
- ***Goal 5: Open Spaces, Scenic and Historic Areas, and Natural Resources.*** Goal 5 encompasses 12 different types of resources, including wildlife habitats, mineral resources, wetlands and waterways. It establishes a process through which resources must be inventoried and evaluated. If a resource or site is found to be important, the local government has three policy choices: to preserve the resource, to allow the proposed uses that conflict with it or to establish some sort of a balance between the resource and those uses that would conflict with it.
- ***Goal 6: Air, Water and Land Resources Quality*.** This goal requires local comprehensive plans and implementing measures to be consistent with state and federal regulations on matters such as stream quality and groundwater pollution.
- ***Goal 7: Areas Subject to Natural Disasters and Hazards*.** Goal 7 deals with development in places subject to natural hazards such as floods or landslides. It requires that jurisdictions apply "appropriate safeguards" (floodplain zoning, for example) when planning for development there.
- ***Goal 8: Recreation Needs.*** This goal calls for each community to evaluate its areas and facilities for recreation and develop plans to deal with the projected demand for them. It also sets forth detailed standards for expedited citing of destination resorts.
- ***Goal 9: Economy of the State.*** Goal 9 calls for diversification and improvement of the economy. It asks communities to inventory commercial and industrial lands, project future needs for such lands, and plan and zone enough land to meet those needs.
- ***Goal 10: Housing.*** This goal specifies that each city must plan for and accommodate needed housing types (typically, multifamily and manufactured housing). It requires each city to inventory its buildable residential lands, project future needs for such lands, and plan and zone enough buildable land to meet those needs. It also prohibits local plans from discriminating against needed housing types.
- ***Goal 11: Public Facilities and Services.*** Goal 11 calls for efficient planning of public services such as sewers, water, law enforcement and fire protection. The goal's central concept is that public services should to be planned in accordance with a community's needs and capacities rather than be forced to respond to development as it occurs.

- ***Goal 12: Transportation.*** The goal aims to provide "a safe, convenient and economic transportation system." It asks for communities to address the needs of the "transportation disadvantaged."
- ***Goal 13: Energy.*** Goal 13 declares that "land and uses developed on the land shall be managed and controlled so as to maximize the conservation of all forms of energy, based upon sound economic principles."
- ***Goal 14: Urbanization.*** This goal requires all cities to estimate future growth and needs for land and then plan and zone enough land to meet those needs. It calls for each city to establish an urban growth boundary (UGB) to "identify and separate urbanizable land from rural land." It specifies seven factors that must be considered in drawing up a UGB. It also lists four criteria to be applied when undeveloped land within a UGB is to be converted to urban uses.
- ***Goal 15: Willamette Greenway.*** Goal 15 sets forth procedures for administering the 300 miles of land along the Willamette River.
- ***Goal 16: Estuarine Resources.*** This goal requires local governments to classify Oregon's 22 major estuaries in four categories: natural, conservation, shallow-draft development and deep-draft development. It then describes types of land uses and activities that are permissible in those "management units."
- ***Goals 17, 18 and 19: Coastal Shorelands, Beaches and Dunes, and Ocean Resources.*** These goals, which specify how certain coastal and ocean resources should be managed and conserved, are not related to the City of Portland's watershed planning and management activities.

Title 3 of Metro's *Urban Growth Management Functional Plan*

Origin and Purpose of Title 3

Metro's *Urban Growth Management Functional Plan* (Section 3.07 of the Metro Code, Metro 2003) provides tools for local governments in the Portland metropolitan area to help meet goals in the 2040 Growth Concept, Metro's long-range growth management plan. Title 3 (Metro Code Sections 3.07.310 - 3.07.370) of the *Urban Growth Management Functional Plan* is intended to address water quality, floodplain management, and fish and wildlife conservation in the region through the development of performance standards for the protection of streams, rivers, wetlands and floodplains. Title 3 specifically implements Oregon Statewide Planning Goals 6 and 7 by limiting encroachment into vegetated "water quality resource areas," and by requiring special provisions to prevent erosion and impacts on flood hazards. In addition to adopting performance standards, Metro also adopted a model ordinance that local governments can use to be in compliance with the Title 3 standards.

Title 3 implements Oregon Statewide Land Use Goals 6 and 7 by limiting encroachment into vegetated "water quality resource areas" and by preventing erosion and flood hazards.

The purpose of Title 3's water quality performance standards is to protect and allow enhancement of water quality. The key water quality provision requires a vegetated corridor along streams and around wetlands, with the corridor width based on the area drained by the stream and the topography of the area. For primary water features (which include perennial streams draining more than 100 acres, wetlands, natural lakes and ponds), the corridor ranges from 50 to 200 feet, depending on the slope. For secondary water features (which include intermittent streams) draining more than 50 acres, the corridor ranges from 15 to 50 feet. Metro's standards do not apply to perennial streams draining less than 100 acres or intermittent streams draining less than 50 acres. The performance standards require erosion and sediment control, planting of native vegetation on the streambanks when new development occurs and prohibition of the storage of uncontained hazardous material—for new uses—in water quality areas.

Title 3's performance standards to protect against flooding are aimed at limiting development in a manner that requires balanced cut and fill[6] and requires floor elevations of buildings and structures to be at least one foot above the flood hazard standard. The areas subject to these requirements are the Federal Emergency Management Agency (FEMA) 100-year floodplain and the area of inundation for the February 1996 flood; these areas have been mapped and adopted by the Metro Council. Metro also developed a *Water Quality and Floodplain Protection Plan* (Metro 2002b) that requires local jurisdictions to meet regional performance standards relating to water quality and floodplain management. The water quality and floodplain protection requirements apply only to new development and large redevelopment projects. The plan was adopted in November 1996 by the Metro Council but did not go into effect until a model ordinance and set of maps were adopted in June 1998.

Under the *Water Quality and Floodplain Protection Plan* (Metro 2002b), only native vegetation can be used to enhance or restore the health of vegetated corridors along the region's streams, wetlands and other water features. Metro's Native Plant List identifies the species of plants that are native to the metropolitan area and also those that are nonnative and considered nuisance species. The plant list is designed to do the following:

- Ensure the continued viability and diversity of native plant communities
- Promote the use of plants naturally adapted to local conditions
- Educate citizens about the region's natural heritage and the values and uses of native plants

The City's Response to Title 3

The foundation of the City's compliance with the water quality portion of Title 3 is found in overlay zones that protect Title 3 Water Quality Resource Areas along the Willamette River and tributary streams. The major components of this compliance package are

[6] Balanced cut and fill requires that any floodplain area that is filled with permanent material (such as emplacement of a bridge abutment) must be offset by an equal excavated area such that the net amount of floodplain storage is unchanged.

Environmental Overlay Zone Regulations and Greenway Overlay Zone Regulations, which are described below. The compliance package also includes other key City programs for stormwater management, the reduction of sewer overflows into the Willamette River and Columbia Slough, cleanup of the Portland Harbor, revegetation of degraded areas with native trees and plants, and funding of community stewardship projects. Together, these programs meet, and in many cases exceed, Title 3 performance standards.

Title 13 of Metro's *Urban Growth Management Functional Plan*

Metro recently adopted the Nature in Neighborhoods Program—Title 13 of the *Urban Growth Management Functional Plan*—to protect, conserve, and restore the Portland metropolitan region's fish and wildlife habitat. The program was developed in stages as follows:

- Step 1: An inventory was completed of regionally significant fish and wildlife habitat, which included conducting scientific research, listing criteria, mapping and ranking natural resources that provide riparian functions and riparian and upland wildlife habitat. Metro's inventory methodology was reviewed by an independent team of scientists.
- Step 2: The economic, social, environmental and energy (ESEE) impacts were analyzed. Metro's analysis identified the consequences and tradeoffs of protecting—or not protecting—inventoried natural resources.
- Step 3: Metro developed, adopted, and is implementing a program to achieve the goals of the planning effort. It emphasizes the balance of resource protections and economy and focuses on protecting, conserving and restoring high value riparian resources. The plan emphasizes strategies such as incentives, public education programs, acquisition, and stewardship, in addition to regulations.

Metro submitted Title 13 to the Oregon Department of Land Conservation and Development for acknowledgement in accordance with Oregon Administrative Rules pertaining to Goal 5. The City has applied environmental overlay zones that provide some level of protection for many of the resource areas that Metro included in the Title 13 Program. Portland and other Metro area cities and counties will be required to demonstrate substantial compliance with Title 13 requirements within two years from acknowledgement by the Oregon Department of Land Conservation and Development (estimated to be required by mid-2008).

The City's Natural Resource Inventory Update

The City of Portland has initiated an update to its existing natural resource inventories of streams, riparian areas and wildlife habitat within the watersheds of Johnson, Tryon and Fanno creeks, the Columbia Slough and the West Hills. This project is part of the City's River Renaissance vision for a clean and healthy Willamette River and tributary watersheds. The products of this work will be used to inform various activities to protect and restore natural resources and advance the City's compliance with regional, state and federal regulations, including setting land acquisition and restoration priorities, updating City regulations, and targeting public education efforts.

The City's Environmental Overlay Zone Regulations

Chapter 33.430 of Portland's Zoning Code governs proposed development in the environmental overlay zones. Environmental overlay zones apply to almost 20,000 acres of significant natural resources in Portland and urbanizing Multnomah County. The Environmental Protection Zone regulations restrict most types of development to protect the highest value resources. The Environmental Conservation Zone allows development that meets specific standards to reduce impacts on natural resources. Development standards include the following:

- Limits on disturbance in resource areas
- Setbacks from streams, wetlands and high-value resource areas
- Requirements for tree removal and replacement
- Native plant requirements
- Standards for land divisions

Together, the environmental zone development standards and approval criteria work to ensure that impacts on significant natural resources are avoided where possible or are mitigated where encroachment is unavoidable. The environmental zoning program is the City's primary tool for compliance with Goal 5 and serves the purposes of Goals 6 and 7. This program is also a significant component of the City's compliance with Metro Title 3 and will be central to the City's compliance with Title 13. The environmental zoning program is also a component of the City's Stormwater Plan and MS4 permit.

The City's Greenway Overlay Zone Regulations

Within the Willamette Greenway, the City has established the "n" and "q" overlay zones to protect natural resources and meet Metro's Title 3 water quality requirements. Applicants for development in these areas must go through special review procedures to avoid, limit and/or mitigate impacts on natural resources and water quality. The City has initiated a project called the River Plan that will result in an update to the Greenway Plan and codes. The new plan will also continue to serve as the City's program to comply with Goal 15 and Metro's Titles 3 and 13.

Other City Programs

A number of other City programs operate in concert with above-mentioned regulatory programs, including the City's Environmental and Greenway Overlay Zones. These include the City's Stormwater Management Program, water quality protection in the Columbia South Shore area, CSO reductions and the Portland Harbor cleanup.

Stormwater Management Program. The City's Stormwater Management Program requires all new and redevelopment projects to comply with a comprehensive set of regulations. Stormwater systems are required to remove pollutants, and in most parts of the City, ensure that flows are managed onsite. The program also encourages retention and enhancement of tree canopy through established "best management practices," and through regulations that allot stormwater management credit for trees on properties and parking strips. Tree canopy is important for stormwater management because it intercepts precipitation and reduces or delays runoff to streets and storm sewers.

The City's stormwater management regulations apply to development in Title 3 Water Quality Resource Areas. Thus, these regulations help meet the intent and performance standards for providing a vegetated corridor; maintaining and reducing stream temperatures; minimizing erosion, nutrient and pollutant loading into water; enhancing infiltration; and providing natural water purification.

Columbia South Shore Water Quality Protection. The City of Portland regulates development to protect groundwater and surface water quality in the Columbia South Shore area. City code regulates land uses that typically involve the use of hazardous materials. The regulations are designed to prevent spills that would contaminate the City's backup drinking water wells. In so doing, the regulations also help meet Title 3 standards for protection of Water Quality Resource Areas in the Columbia Slough Watershed.

CSO Reduction and Portland Harbor Cleanup. The City's investments in reducing combined sewer overflows into the Willamette River and Columbia Slough also contribute to removal of pollutants from entering Protected Water Features. Portland's participation in the Portland Harbor cleanup will help identify sources of pollution that is conveyed to the Willamette through the stormwater system within the Superfund site.

Additional Programs. Voluntary programs such as the City of Portland's Watershed Revegetation, Community Stewardship, and Naturescaping for Clean Rivers programs support Title 3 standards that call for restoration of degraded Water Quality Resource Areas. These programs are managed by Portland's Bureau of Environmental Services and provide financial incentives and technical support to the community for proactive restoration of degraded areas.

APPENDIX C

Existing City Activities the *Framework* Builds Upon

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Existing City Activities the *Framework* Builds Upon

The watershed management system described in the *Framework* builds on the momentum of City initiatives and efforts already under way to address watershed and river health. These include, but are not limited to, the following City of Portland programs and activities:

Assessment of City of Portland Activities for Potential to Affect Steelhead. The City of Portland commissioned this assessment in 1998 to determine whether City activities have the potential to affect steelhead and steelhead habitat. Activities assessed include planning, permitting, inspection and enforcement; water delivery; stormwater and wastewater management; structure and road construction and maintenance; environmental enhancement; and emergency response. The assessment also evaluated Endangered Species Act compliance approaches and potential conservation strategies for Portland-area watercourses used by steelhead and other salmonids.

Clean River Plan. The Clean River Plan sets forth a comprehensive approach to catching and treating stormwater before it enters the sewer system or reaches a receiving stream. The Clean River Plan was designed as a major supplement to the Combined Sewer Overflow (CSO) Abatement Program to more effectively and efficiently address sewer overflows and bacterial pollution, as well as overall watershed health and stewardship. It uses a variety of innovative techniques to reduce stormwater runoff, reduce pollutant levels, restore floodplains and foster environmental education and stewardship.

Combined Sewer Overflow (CSO) Abatement Program. The CSO Program is designed to control combined sewer overflows to the Willamette River and Columbia Slough. The City of Portland has already completed combined sewer overflow reduction projects for the Columbia Slough that reduce the volume of combined sewer overflows by more than 99 percent. Westside CSO projects under construction include the West Side Big Pipe project. The 14-foot-diameter Big Pipe tunnel runs parallel to the Willamette River for four miles. The pipe will collect and store wastewater from existing sewers and convey it under the river to the new Swan Island Pump Station, from which it will be pumped to the Columbia Boulevard Wastewater Treatment Plant. A companion pipe, which is likely to be 20 to 24 feet in diameter, will be built on Portland's east side by 2011. The combined capacity of the new pipes will reduce CSOs to the Willamette River by a minimum of 96 percent.

Development Standards. Development standards have been put in place to comply with the City's National Pollutant Discharge Elimination System (NPDES) MS4 permit (for municipal separate storm sewer systems) and the City's policies pertaining to a sustainable environment and the recovery of threatened or endangered species. The City of Portland's *Stormwater Management Manual* (City of Portland Bureau of Environmental Services 2000), for example, requires specific measures to reduce the impacts of stormwater runoff and pollution resulting from new development and redevelopment within the City. Some key requirements are as follows:

- Removal of at least 70 percent of total suspended solids in stormwater
- Removal of pollutants of concern in water quality-limited waterbodies (meaning those with total maximum daily load [TMDL] limits)
- Management of stormwater runoff once construction is completed
- Suggested best management practices. Using eco-roofs, vegetated swales and public education helps reduce, retain and filter stormwater runoff onsite instead of it being discharged directly to streams.

The City of Portland's *Erosion Control Manual* (City of Portland 2000) provides guidelines that require all sites of ground disturbance to comply with a "no visible or measurable" sediment discharge standard. There also are enhanced controls for large, sloped and sensitive development sites. Erosion, sediment and pollutant control plans are required for all sites needing a City permit.

In addition, the watershed management process presented in Chapter 3 of the *Framework* guides the development of individual watershed management plans for Portland's urban watersheds. Each watershed management plan will include assessments of water quality and flow that will lead to recommendations for new or revised stormwater management program elements or best management practices (BMPs) that would help the City of Portland meet the requirements of its NPDES stormwater permit and other regulatory obligations. The watershed management plans will identify projects and actions to restore natural stormwater infiltration functions and stormwater retention, as well as fish and wildlife habitat.

Endangered Species Act Program. The City of Portland initiated its Endangered Species Act (ESA) Program in 1998 to manage the City's activities in response to the listing of salmonids under the federal Endangered Species Act. The Endangered Species Act Program is designed to be comprehensive, based on sound science and focused on action. The program's aim is to go beyond the minimum standards set by the ESA (that is, to avoid "take") to help the City of Portland achieve its goal of assisting with the recovery of native fish and wildlife. In addition, the program acts to empower, engage and motivate the community and City government to act strategically and proactively so that the greatest overall community, economic and environmental benefits are achieved. The ESA Program became part of the Bureau of Environmental Services' Science, Fish and Wildlife Division, within the Watershed Services Group, in 2005.

ESA Section 7 Streamlining Agreement. In October 2002, the City entered into a federal ESA Section 7 streamlining agreement with the National Marine Fisheries Service in the National Oceanic and Atmospheric Administration (NOAA Fisheries), the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service (USFWS). This agreement establishes a cooperative process for streamlining ESA Section 7 consultations among the four parties to the agreement for City projects that require federal permit approval or funding. Every quarter, City and federal agency staff meet to simplify and streamline Section 7 consultations; develop information, documentation, formats and timeframes for biological evaluations/assessments (BE/BA) and biological opinions; develop additional compliance strategies; and improve coordination of strategies for complying with the ESA and additional regulatory requirements of other state and federal regulatory programs. The streamlining agreement facilitates early planning and coordination among the City and federal agencies for projects, programs and activities that require or would benefit from federal agency review. Benefits of the agreement include increased coordination for review, analysis and documentation of City projects, programs and activities so that they proceed in a timely manner while meeting federal agency and City goals for ensuring ESA compliance and assisting in the conservation of listed species.

Erosion Control. In response to ESA listings, the City assembled a citywide team to expand and improve on the City's erosion control program, which works to reduce erosion and its impacts on fish and their habitat. This effort produced new erosion control regulations as well as a revised erosion control handbook.

Fanno Creek Resource Management Plan. The Bureau of Environmental Services completed the Fanno Creek Resource Management Plan in 1998 as part of the City's Public Facilities Plan. The Fanno Creek Resource Management Plan contains an assessment of resource, habitat, hydrologic and hydraulic conditions in the watershed, and it analyzes areas and subbasins in the Fanno Creek Watershed that generate high pollutant loads. Some actions recommended in the Fanno Creek plan have been implemented. The plan also provided critical technical support to the Planning Bureau's Southwest Community Plan project.

Fish-Friendly Maintenance Practices Manual. The City of Portland's Maintenance Bureau, in conjunction with the Endangered Species Act Program, developed a manual of fish-friendly maintenance practices. The manual was the basis for a City application to NOAA Fisheries for an ESA Section 4(d) "take" limitation program, to help ensure that City road maintenance activities do not harm listed species.

Fish Research. The City's Endangered Species Act Program partnered with the Oregon Department of Fish and Wildlife in 2000 to conduct a 4-year study in the lower Willamette River to evaluate the habitat functions that bank treatments and near-shore developments provide for salmonids. Information was collected on the types of bank treatments and near-shore developments that are preferred, how they are distributed in the lower Willamette, and the specific features that distinguish them from other areas. The results provide the City of Portland with information that will be useful when more certainty is desired regarding planning, permitting and enforcement actions. The work also will help define properly functioning conditions in this reach of the river. The City also is working with the Oregon Department of Fish and Wildlife, Ducks Unlimited and others to conduct fish research in the area's tributary streams. All of Portland's watersheds are being sampled seasonally to determine when fish are present.

Illicit Discharge Controls. The City of Portland has developed an illicit discharge elimination program to prevent, search for, detect and control illicit discharges to the City's stormwater systems and surface waters. The program includes identification and tracking of public and private outfalls, verification of commercial and industrial connections to the City storm system, monitoring to detect non-permitted discharges and evaluation of non-stormwater discharges to the storm system. The City also maintains a Spill Protection and Citizen Response (SPCR) Team to reduce the frequency and impact of spills and inappropriate discharges to the combined sewer system and the storm system.

Industrial/Commercial Controls. The City of Portland oversees facilities that discharge to the City's storm systems from industrial and commercial properties with specific Standard Industrial Classification (SIC) codes. The City reviews all nonresidential facility stormwater pollution control plans and performs site inspections to ensure compliance with the plan and permit conditions. The City also provides technical assistance and programs to identify additional activities and BMPs to minimize pollutants in stormwater runoff.

Integrated Pest Management Program. Portions of Portland Parks and Recreation's Integrated Pest Management Program have been acknowledged by NOAA Fisheries as protective of listed salmon under ESA Section 4(d). Other City bureaus also follow the program to ensure effective and environmentally sound pest management. The City is working with NOAA Fisheries and a variety of environmental and other organizations to continue its ongoing efforts to refine, improve and expand its integrated pest management practices.

Johnson Creek Culvert Replacements. The City of Portland is working with Multnomah County, Clackamas County, Gresham and Milwaukie to coordinate the replacement of culverts throughout the Johnson Creek watershed. The jurisdictions are developing a unified prioritization scheme to identify the culvert replacements that provide the maximum benefit for salmonids. The City of Portland also worked with Metro and state and federal resource agencies to remove a culvert that blocks access to high-quality steelhead habitat in Kelly Creek, a tributary to Johnson Creek, and is working with the U.S. Army Corps of Engineers to remove culverts in Crystal Springs, a tributary to Johnson Creek.

Johnson Creek Restoration Plan. The City of Portland and the Johnson Creek Watershed Council developed a plan to restore habitat, improve flows and reduce flooding in Johnson Creek. The plan, which is aimed at managing floods, includes more than 60 activities that will restore corridor function. An action plan that is based in part on City analyses will help inform City and private protection and restoration priorities.

Natural Resources Inventories and Protection. The City developed and adopted eight natural resources inventories and protection plans:

- Johnson Creek Basin Protection Plan (including the Boring Lava Domes Supplement)
- Columbia Corridor Industrial/Environmental Mapping Project
- Balch Creek Watershed Protection Plan
- Northwest Hills Natural Areas Protection Plan
- Southwest Hills Resource Protection Plan
- East Buttes, Terraces and Wetlands Conservation Plan
- Fanno Creek and Tributaries Protection Plan
- Skyline West Conservation Plan
- Forest Park Natural Resource Management Plan

The adoption of these plans established the City's environmental overlay zones to help ensure protection of important natural features, functions and public health and safety. Environmental overlay zoning regulations help protect waterways and upland natural resource areas by limiting development or requiring development to meet certain standards and criteria to avoid or mitigate impacts on natural resources. Other land use and zoning tools that contribute to the conservation or natural resources include the Greenway Overlay Zone, Natural Resource Management Plans and District Plans.

The Bureau of Planning is updating citywide natural resource inventory information for rivers, streams, drainageways, wetlands, riparian resources and wildlife habitat, along with a natural resource inventory for the Willamette corridor. This new information can be used to help inform many City and community programs and projects such as the *River Plan* for the Willamette corridor, updating existing land use and zoning tools; and watershed management, including setting land acquisition and restoration priorities, and developing strategies to comply with emerging regional and state regulations.

Office of Sustainable Development (OSD). The City of Portland created the OSD to provide leadership and create policies and programs to promote environmental, social and economic health in Portland and to encourage sustainable development to protect our environment and economy for future generations. OSD integrates efforts related to energy efficiency, renewable resources, waste reduction and recycling, green buildings and sustainable practices and education.

Parking Lot Landscaping. The Planning Bureau, Bureau of Environmental Services and Endangered Species Act Program developed new parking lot landscaping requirements designed to reduce water quality and stormwater impacts.

Public Education and Outreach about Stormwater. The City of Portland offers a variety of public education programs about stormwater. Examples include free education programs to schools and community groups and technical assistance and partnerships with businesses and industry groups. The City's education programs also provide community service projects, stewardship grants and curriculum resources.

River Plan. The *River Plan*—a plan for the land along the Willamette River in the City of Portland—will include an update to the *Willamette Greenway Plan*, zoning map, Zoning Code, and design guidelines; development of a working harbor reinvestment strategy for the North Reach; and other implementation strategies. It will be developed in three phases—North Reach (underway) followed by South Reach and Central Reach.   Sequencing will allow the plan to be synchronized with projects and planning efforts that affect different sections of the river. The *River Concept* is a document that will provide policy guidance for the River Plan. A draft *River Plan* is expected to be presented to the Planning Commission and City Council in 2007, and will address Greenway trail alignment, river-dependent/river-related industrial uses, watershed health, natural resources, landscaping and riverbank design issues.

Ross Island. Ross Island Sand and Gravel and the City are negotiating the transfer of Ross Island to the City. The island presents a tremendous opportunity for habitat restoration and long-term research on the costs and benefits of various restoration measures.

Site Development Review Process. The City is undertaking a comprehensive review of all aspects of the administration and enforcement of the City's environmentally related programs. Receiving particular attention in this project are the programs concerning erosion control, stormwater management, trees and landscaping standards, subsurface drainage and the enforcement of site-related conditions and standards from the Zoning Code and Land Use Reviews. The purpose of this review is to ensure the effective administration and enforcement of development regulations that affect the environment. The review will result in recommendations for both substantive and administrative modifications and improvements. Primary areas that will be addressed include code consolidation, regulatory coordination, clarification of responsibilities and procedures, modifications to fee structures and revenue distribution, staff training and expertise, the handling of complaints, and enforcement tools.

Stormwater Management Manual. Stormwater management is a key element in maintaining and enhancing environmental conditions within Portland. The City of Portland has developed a comprehensive stormwater management manual to provide design professionals with specific requirements for reducing the impacts of stormwater runoff and pollution resulting from new development and redevelopment within Portland. The manual's requirements apply to all development, whether public or private. The City and NOAA Fisheries are working together to develop an ESA Section 4(d) "take" limitation proposal based on the *Stormwater Management Manual* (City of Portland 2000).

Structural Controls. The City has created or retrofitted a number of stormwater management facilities to reduce stormwater quantity and improve the quality of stormwater runoff. The City offers incentives and assistance for projects that control stormwater runoff from commercial and industrial properties. This includes disconnection of downspouts, replacement of pavement with porous materials and the use of vegetated swales, planters or other landscape features that assist stormwater management.

Salmon Safe Certification for Portland Parks. The City is working with the independent, third-party environmental certification organization called Salmon Safe to evaluate how "fish-friendly" City parks management is. Certification criteria have been developed and are being applied to a variety of Portland parks. Improvements in park management identified through the certification process will be addressed on an ongoing basis. Portland is the first city to undergo a third-party certification of its parks.

Upper Tryon Creek Corridor Assessment. The Bureau of Environmental Services completed the Upper Tryon Creek Corridor Assessment in 1998 as part of the City's Public Facilities Plan. The corridor assessment analyzes stream corridors in Upper Tryon Creek Watershed and identifies high-priority areas for restorations. The report also contains an assessment of the hydrologic and hydraulic conditions in the watershed. Some actions recommended in this report have been implemented. This report also provided critical technical support to the Planning Bureau's Southwest Community Plan project.

Urban Migratory Bird Treaty. In 2003, Portland became one of four U.S. cities chosen by the U.S. Fish and Wildlife Service to participate in its Urban Conservation Treaty for Migratory Birds. Under this 3-year program, the City receives $50,000 to protect migratory birds that nest in or fly through Portland. As part of the treaty, the City is developing and implementing bird conservation projects, providing matching dollars and in-kind support, and developing partnerships with other metropolitan-area organizations. Activities conducted under the treaty include public education and outreach, habitat improvements such as removal of invasive plants, and removal of hazards to migratory birds.

Willamette River Habitat Restoration and Enhancement Projects. The City of Portland is working to improve fish and wildlife habitats in and along the Willamette River. These projects include, for example, improving fish access to off-channel habitat at Oaks Bottom and Smith and Bybee lakes for resting and rearing of juvenile fish migrating in both the Willamette and Columbia rivers. The City of Portland is restoring portions of the Willamette River streambank as part of the redevelopment of the South Waterfront District and is implementing a number of revegetation projects along with Willamette. Bioengineered bank treatments have been incorporated into a variety of riverfront parks and redevelopments, including the East Bank Esplanade, the Riverplace Development and South Waterfront Park.

Water Resources Development Act (WRDA). The City is partnering with the U.S. Army Corps of Engineers to develop a suite of ecosystem restoration actions under the authority of the federal Water Resources Development Act. Under the Act, the Corps will provide a 50 percent cost share for planning restoration actions and will provide a two-thirds cost-share for implementation. The City is using the analytical approach described in the *Framework* to guide the project selection effort.

Additional Projects. In addition to its programmatic work, the City is engaged in a variety of specific projects that enhance habitat for fish and wildlife in Portland's watersheds. Sample projects include the Columbia Slough 1135 project, in which the City is partnering with the U.S. Army Corps of Engineers and Multnomah County Drainage District to modify channel and culvert conditions in the slough, create wetlands and restore portions of the riparian buffer/wildlife corridor along the slough. Other examples are green street projects, in which curb extensions are landscaped to filter runoff and reduce the stormwater flowing into the sewer; eco-roofs, which replace conventional roofing with vegetated roofing that reduces stormwater runoff, pollution and erosion; and downspout disconnections, in which roof drains from commercial and institutional buildings are disconnected and stormwater is directed over the ground for filtration or for treatment and discharge. These projects are being implemented through the City's Sustainable Stormwater Program and Innovative Wet Weather Program, which is funded in part through grants from the U.S. Environmental Protection Agency. The City also has purchased properties—including riparian areas—for purposes of flood storage, natural parks and resource protection and restoration.

Appendix D

Regional Coordination and Integration

APPENDIX D

Regional Coordination and Integration

The Portland City Council's directive to achieve clean and healthy river conditions and watersheds and assist with the recovery of federally listed salmonids must be carried out with coordination and collaboration with other entities—both public and private—within the entire Willamette watershed and the entire range of the evolutionarily significant units (ESUs) of the listed species. Although the City of Portland will focus attention on achieving watershed health within its own watersheds, it will also conduct its efforts within a regional context that includes the Columbia River and various upstream and downstream communities and resources. For example, the City will consider (and where appropriate may integrate) regional planning and recovery actions such as those outlined in *Wy-Kan-Ush-Mi-Wa-Kush-Wit: The Spirit of the Salmon* (Columbia River Intertribal Fish Commission 1995), NOAA Fisheries recovery plans and biological opinions, Northwest Power and Conservation Council subbasin plans and the Oregon Plan for Salmon and Watersheds in the Columbia and Willamette river basins. In addition, Portland's geographic location is an important factor in water quality and salmon recovery; this means that decisions and actions taken by jurisdictions upstream from Portland need to be coordinated with the City of Portland because those actions will affect local conditions and, consequently, decisions made by the City. Similarly, the City of Portland needs to coordinate with upstream jurisdictions to make sure that upstream investments are not diminished by actions (or inaction) in Portland.

For this reason, the City of Portland has taken a variety of steps to ensure that its actions are consistent with actions taken by other entities within the Willamette watershed and within the ranges of the ESUs of listed species. The City also is attempting to capture basinwide habitat, water quality and other information at the appropriate scale to inform its decisions.

The City of Portland is playing an active role in a number of collaborative regional efforts to restore fish and wildlife and improve water quality and watershed conditions. Portland's collaborative approach builds partnerships with federal, state, tribal and other local governments throughout the region and with the public. It integrates several different planning efforts, including ESA recovery planning, Northwest Power and Conservation Council subbasin planning, state salmon recovery planning, state water quality planning and regional wildlife planning, into a single watershed-based approach. This approach will do the following:

The City is integrating multiple planning efforts, from ESA recovery planning to regional water quality planning, into a single, watershed-based approach.

- Ensure consistency in goals, strategies, actions and priorities across the region
- Avoid costly duplication of efforts and provide economy of scale
- Establish a partnership of federal, state, tribal and local agencies and the public for effective and efficient coordination of research, planning, implementation and monitoring efforts for protection and restoration of watershed health

Portland participates in the following activities, among others:

- **Federal ESA recovery planning efforts** administered by NOAA Fisheries (for listed Chinook salmon, chum salmon and steelhead) and the U.S. Fish and Wildlife Service (for bald eagles, cutthroat trout and other species). Portland participates on the NOAA Fisheries Executive Committee guiding the development of a recovery plan for listed species in the Willamette and lower Columbia region. The plan is being created through a collaborative effort involving federal and state agencies, tribes, local governments and the public. The City will use the process described in this *Framework* to create the portion of the NOAA recovery plans that address the area within Portland's jurisdiction.
- **Development of a Northwest Power and Conservation Council (NPCC) subbasin-level recovery plan** for the Willamette Basin that will help protect, provide mitigation for and enhance fish and wildlife populations adversely affected by the development and operation of the Columbia River Power System. The completed subbasin plan for the Willamette Basin will be adopted as part of NPCC's Columbia River Basin Fish and Wildlife Program and will help direct Bonneville Power Administration (BPA) funding of watershed-related projects. Through the Willamette Restoration Initiative (WRI, see below), Portland staff are working on planning and technical elements of the Willamette Subbasin Plan, and the City has a representative on the board of WRI.
- **The Willamette Total Maximum Daily Load (TMDL) Council**, a group of "stakeholders" formed by the Oregon Department of Environmental Quality (DEQ). The council is working on developing TMDLs and load allocations for individual designated management agencies (DMAs), modeling management scenarios and preparing a water quality management plan. The DMAs will then draft implementation plans. Representatives of agriculture, municipalities, industry, the tribes, fishing, forestry, developers, government, federal dam operators and environmental groups have been invited to participate. The City of Portland participates in the council via membership in the Association of Clean Water Agencies (ACWA), which has two positions on the council.
- **Technical activities.** The City of Portland has collected riparian and instream habitat observations for each of its watersheds using the protocol in the *Oregon Watershed Enhancement Manual* (Governor's Watershed Enhancement Board 1999). The City is using the EDT model developed by the Northwest Power and Conservation Council and others to assess habitat conditions and prioritize protection and restoration actions. The City's approach is modeled after the Northwest Power and Conservation Council's subbasin planning process. The City has partnered with the Oregon Department of Fish and Wildlife (ODFW) to conduct fish research and complete ODFW's regional fish data set. The City of Portland has an Intergovernmental Agreement with DEQ to facilitate collaboration and integration on pollution source control and stormwater issues.
- **Intergovernmental planning.** The City of Portland created an intergovernmental agreement with Seattle and other Puget Sound jurisdictions to develop a consistent conceptual foundation for the recovery of salmonids in an urban context. City staff also participate in the Willamette Urban Watershed Network and the Oregon Plan for Salmon and Watersheds Implementation Team.

- **Local collaborations.** Portland collaborates actively with the Johnson Creek Interjurisdictional Committee, local watershed councils and neighboring jurisdictions, such as Washington County's Clean Water Services and Clackamas County's Water and Environment Services.
- **Portland River Trust.** Portland has established a "River Trust" with the U.S. Environmental Protection Agency (EPA), NOAA Fisheries and the U.S. Army Corps of Engineers. Success in enhancing watershed health will be accomplished through effective partnerships and more effective intergovernmental working relations with relevant federal and state agencies. The Portland River Trust is the key to bringing those agencies together. It is the mechanism for establishing a new and more effective relationship among the federal, state and local government entities that make key decisions on the future of the lower Willamette River. The Portland River Trust is designed to help the City and federal agencies address river issues more comprehensively and to allow local needs and creativity to meet and surpass federal requirements. The partnership is defined by an agreement from all levels on specific goals, measures and benchmarks.

There is no single entity responsible for planning at the regional watershed or ESU scale. As the City begins to apply the watershed management process in the *Framework*, more emphasis will be placed on working with the state and NOAA Fisheries to improve integration of efforts of multiple entities. The City believes that its approach is consistent with or supportive of approaches being used by other jurisdictions and agencies and, more importantly, that the tools and techniques it is developing can be adjusted to ensure that Portland's work fits well within the broader regional efforts.

The tools and techniques presented in the *Framework* can be adjusted to ensure that Portland's work fits well within broader regional efforts to improve watershed health.

In the absence of a fully integrated regional approach, the City of Portland believes that its strategies and techniques will result in scientifically sound actions that can be implemented and measured within the City's legal constraints.

In the meantime, numerous state and local regulations, programs and activities have important linkages to the City of Portland's efforts to achieve watershed health. The City plans to continue to be involved in, coordinate with and exchange information with these programs and activities to help improve integration across jurisdictional responsibilities and boundaries. In addition, the City will continue to recommend to NOAA Fisheries, the state government of Oregon, the Northwest Power and Conservation Council and other entities ways to improve coordination and integration of efforts within Portland at larger geographic scales.

Additional Active Local and Regional Partnerships and Collaboration

In addition to the activities described above, the City of Portland's integrated watershed planning efforts include active partnerships or collaboration with the following:

Lower Willamette Group. The City is a member of this group composed of parties potentially responsible for the Portland Harbor Superfund cleanup being conducted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

Metro ESA Coordinators Group. The Metro ESA Coordinators Group is made up of natural resource and planning staff representing many of the 23 government jurisdictions within the boundary of the Portland area's regional government, Metro. The group meets monthly to share information and provide a single forum for federal and other natural resource staffs to provide briefings and answer questions.

Oregon Plan for Salmon and Watersheds. Governor Kitzhaber unveiled his Oregon Plan for coastal salmon recovery in August 1996. This plan and a subsequent steelhead supplement and Executive Order in January 1999 committed state agencies to enforce environmental laws, coordinate activities for protecting listed salmonids and provide technical assistance to local conservation activities. The plan's stated goal is "to restore salmon to a level at which they can once again be part of people's lives." The Oregon Plan identified how private interests could work through local watershed councils, identified restoration activities on forest lands to be completed by forest industries and identified water quality planning opportunities at a basin level. The City of Portland, which has participated on the Oregon Plan Implementation Team, is committed to embracing the goals and approaches in the Oregon Plan.

Oregon Subbasin Planning Coordination Group. This group is made up of key state, federal and tribal agencies responsible for managing fish, wildlife and other natural resources. The group is responsible for organizing and managing the State of Oregon's work related to the Northwest Power and Conservation Council's subbasin planning process. The group also manages a team of state technical experts who support local planners.

Puget Sound Coordination on Urban Blueprint for Restoration. The City of Portland worked with cities in the Puget Sound region (Seattle, Tacoma, and Bellingham) to identify and discuss issues common to the restoration of salmon in urban watersheds, and to discuss and negotiate common elements with NOAA Fisheries.

Willamette Restoration Initiative (WRI). Established by the Governor of Oregon in response to recommendations from the Governor's Willamette River Task Force, the Willamette Restoration Initiative (WRI) is an ongoing project that seeks to coordinate efforts to protect and restore the watershed's health. The WRI has no legal authority but is intended to collaborate with various organizations (such as local governments, soil and water conservation districts, and other groups and programs) to provide a unified regional approach to improving fish and wildlife habitat, enhancing water quality and managing floodplains in the Willamette Basin, within the context of human habitation and projected population growth.

The WRI is serving as the lead entity for developing the "Willamette Subbasin Plan" as part of NPCC's program to protect, mitigate, and enhance fish and wildlife of the Columbia River Basin and to make annual funding recommendations to BPA for projects to implement the program. In developing the subbasin plan, WRI is working closely with its extensive stakeholders network, local groups, private and public technical experts, state and federal wildlife, land and water managers, NOAA Fisheries, the U.S. Fish and Wildlife Service

(USFWS), the U.S. Army Corps of Engineers, the Oregon Department of Fish and Wildlife (ODFW), area tribes, the Oregon Coordinating Group and the Technical Outreach and Assistance Team (TOAST). The WRI intends to complete subbasin planning products in May 2004.

The subbasin plan will document subbasin conditions and evaluate and define strategies that will drive the implementation of the Council's Fish and Wildlife Program at the subbasin level. Fish and wildlife population and habitat management goals and objectives, including harvest, natural and hatchery production will be developed for a 10- to 15-year horizon. Strategies to meet goals for habitat protection and restoration will be prioritized in collaboration with local stakeholders in the planning process. NOAA Fisheries and USFWS will also use the plan in their recovery planning efforts for threatened and endangered species. The plan will be evaluated for consistency with the Clean Water Act, the Endangered Species Act and federal treaty and trust responsibilities with the basin's Native American tribes. As intended by NPCC, the subbasin planning process will rely mostly on existing assessment information and focus the majority of effort on the management plan and strategies.

The WRI will rely on multiple partnering organizations in developing the subbasin plan. The City of Portland is playing an important coordinating role with the WRI as it prepares the Willamette Subbasin Plan. The City is providing in-kind and consultant services to the process. WRI will be creating technical and policy teams and engaging in some public process as it develops the Willamette Subbasin Plan. This will occur at the same time the City is developing the Willamette Watershed Plan, the Water Resources Development Act (WRDA) General Investigation and the River Renaissance Plan.

WRI anticipates spending significant time developing multiple Ecosystem Diagnosis and Treatment (EDT) models and assessing wildlife populations and habitat needs. A key element of the in-kind services being provided is the City's EDT analysis of Portland's waterways, including the Lower Willamette, Johnson Creek and Fanno-Tryon creeks. In addition to Portland's EDT work, WRI is committing to conducting EDT analyses on two additional Willamette tributaries: the Clackamas and McKenzie rivers. WRI is working with groups in both watersheds to get a start on this effort. The City of Portland has been working with Clackamas County Water and Environment Services on applying EDT in the Clackamas River watershed.

WRI also is working with other partners to secure additional resources for the subbasin planning effort, notably the U.S. Army Corps of Engineers. Since 1996, the Corps has been working on a major investigation dealing with floodplain restoration. After examining the content and process of subbasin planning, the Corps determined that it can provide a critical context for any additional floodplain study in the basin. Because WRI is the lead entity in subbasin planning, the Corps has approached WRI about being a nonfederal sponsor of further floodplain restoration research.

Willamette Urban Watershed Network. The Willamette Urban Watershed Network (WUW-Net) is a group of environmental professionals who have volunteered to work toward watershed health and salmon recovery in the urban areas of the Willamette River Basin. The purpose of the WUW-Net is to promote collaboration among local, state and federal agencies to help solve watershed and species problems related to urbanization. An important focus of this effort is addressing Endangered Species Act compliance and species recovery needs in the urban setting. WUW-Net provides a unique forum for the City of Portland to share information and collaborate on basinwide issues.

Other Key Sources of Pertinent Information or Information Exchange

The City of Portland's integrated watershed management efforts also consider the following as key sources of pertinent information or information exchange:

Columbia River Inter-Tribal Fish Commission. The Inter-Tribal Fish Commission supports salmon recovery through the protection and restoration of watersheds in the Columbia Basin (Columbia River Inter-Tribal Fish Commission 1995). This effort emphasizes the importance of the entire watershed, including uplands, to well-functioning rivers and streams and is based on science, ecology and traditional Native American understanding of and respect for the natural world. It includes healthy human communities as part of healthy landscapes. The Inter-Tribal Fish Commission endorsed the *Oregon Watershed Assessment Manual* (Governor's Watershed Enhancement Board 1999) as a good watershed assessment resource.

King County, Washington. King County has embarked on regional watershed planning and implementation, reflecting governmental response to habitat degradation caused by the Seattle region's large population and growth rates over the past decades. King County and others have initiated the Puget Sound Ecosystem Restoration Initiative, a proposed program to restore habitat for salmon and other species throughout the Puget Sound Basin (Tri-County Salmon Conservation Coalition, Tri-County Model 4(d) Rule Response, April 19, 2002, www.salmoninfo.org). The initiative's goals are to identify, prioritize and construct the most effective habitat projects in the 17 watersheds in the basin. This science-based plan may provide an excellent model for similar efforts in the Portland area.

Lower Columbia River Estuary Plan. The Lower Columbia River Estuary Plan's mission is to preserve and enhance the water quality of the estuary to support its biological and human communities (Jerrick 1999). Developed by the governors of Oregon and Washington, the U.S. Environmental Protection Agency and other parties, this project relates to the Portland area because the water, and all of the sediments and pollutants contained therein, derive from or pass through the Portland area to reach the estuary—an excellent example of cumulative effects. The Estuary Plan offers strategies for aquatic ecosystem monitoring, information management and a program for analysis and inventory. The Estuary Plan's board is currently working with NOAA Fisheries to tie its efforts more closely to Endangered Species Act-related salmonid conservation efforts.

Metro's Regional (Goal 5) Fish and Wildlife Habitat Protection Program. Part of Metro's Nature in the Neighborhood initiative, the Regional (Goal 5) Fish and Wildlife Habitat Protection Program establishes minimum standards for consistent protection of Class I and Class II riparian areas in the Portland Metro region—standards that governments within the Metro area will, for the most part, be required to comply with. Class I and II riparian areas are the highest value stream corridors, floodplains and headwater streams, which provide ecological functions such as shade, pollution control, flood storage and nutrient cycling for nearly 300 native fish and wildlife species in the region. The Regional Fish and Wildlife Habitat Protection Program also promotes habitat-friendly development through a suite of voluntary, incentive-based nonregulatory measures, and it proposes a regional bond measure in 2006 to acquire natural areas as public-access open space. In addition, the program is consistent with Oregon's Statewide Planning Goal 5, which requires that natural resources be inventoried and evaluated (see "Key State and Regional Regulations" in Appendix B).

NOAA Fisheries Technical Recovery Team. NOAA Fisheries has formed a Technical Recovery Team (TRT) for the Lower Columbia River evolutionarily significant units (ESUs) of steelhead trout and Chinook salmon. This team will be responsible for setting viable salmonid population goals for the ESU (see Appendix F). The City of Portland will work with the TRT to ensure that the City's watershed and habitat conservation efforts are consistent with salmonid recovery planning throughout the region. NOAA Fisheries also has formed an executive committee to assist the TRT in developing a recovery plan for the Willamette and lower Columbia rivers. The City of Portland is a member of this executive committee.

Northwest Habitat Institute. This Corvallis, Oregon-based nonprofit scientific and educational organization (www.nwhi.org/nhi/default.asp) has produced an online "Interactive Biodiversity Information System" that includes wildlife-habitat relationship data for native species and habitats of the northwestern U.S. The Northwest Habitat Institute has used this database to determine the extent to which ecosystems are currently "fully functional" and how functions have changed or been compromised by land use activities, as well as to help identify and prioritize areas for protection and restoration. The City of Portland will make use of the Northwest Habitat Institute's information as it addresses the terrestrial components of watershed management.

Northwest Power and Conservation Council (NPCC). The Northwest Power Act, passed in 1980, created the Northwest Power and Conservation Council to give the governors of Oregon, Washington, Montana and Idaho valuable tools for use in addressing energy, fish and wildlife concerns in the region. The Council has developed a Columbia River Basin fish and wildlife program that guides the mitigation and restoration actions undertaken by the Bonneville Power Administration (Northwest Power and Conservation Council 2001). These tools include substantial input into the investment of power ratepayer money in energy, fish and wildlife initiatives; an open forum for public debate; and the capability to provide high-quality, independent analyses of complex resource issues. The Council's responsibility is to mitigate the impact of hydropower dams on all fish and wildlife in the Columbia River Basin through a program of enhancement and protection, and to provide guidance and recommendations on projects funded through Bonneville Power Administration revenues. (The cost of these projects amounts to hundreds of millions of dollars per year.) The Council has undertaken a number of important restoration-related activities in recent years, including input on subbasin inventory, assessment and planning; development of a fish and wildlife program for the Columbia Basin; and publication of several major scientific reports.

Oregon Watershed Enhancement Board (OWEB). The Oregon Watershed Enhancement Board administers State Lottery proceeds to fund watershed restoration projects and support watershed councils. OWEB will collaborate with the federal government as it implements its mission to promote and implement programs to restore, maintain and enhance watersheds in Oregon, and to protect the economic and social well-being of the state and its citizens.

Pacific Northwest Ecosystem Research Consortium (PNERC). PNERC is an interdisciplinary research group made up of scientists from Oregon's state universities, EPA, private research consultants and others (Pacific Northwest Ecosystem Research Consortium 2002). The consortium's goals are to understand the ecological consequences of societal decisions in the Pacific Northwest, develop transferable tools to support management of ecosystems at multiple spatial scales and strengthen linkages between ecosystem research activities and ecosystem management applications in the Pacific Northwest. Specific objectives are to characterize ecosystem condition and change, identify and understand critical processes and evaluate outcomes (including modeling alternative future scenarios and potential consequences of these alternatives to humans and the environment). PNERC offers several data products, including maps modeling Willamette Valley land use from the 1850s and existing habitats in the Willamette Valley, and Habitat Suitability Index models for wildlife species in which wildlife trends may be modeled under various future alternatives.

Port of Portland Riverbank Management Program. Since 1997, the Port of Portland's Marine Division has managed the 11 miles of riverbank that it owns along the Willamette and Columbia rivers to protect the property from erosion and provide wildlife habitat. As part of this voluntary, comprehensive program, the Marine Division removes nonnative vegetation, plants native species, uses geotextile fabric wraps and large wood structures to stabilize the riverbank, and conducts annual surveys and monitoring. In 2005 the Marine Division reconstructed five acres of riverbank at Toyota's facility in St. John's.

Tualatin Basin Goal 5 Planning Process. A Tualatin Basin consortium of ten cities, Washington County, Clean Water Services and the Tualatin Hills Parks and Recreation District, in coordination with Metro, will develop its own basin-wide fish and wildlife habitat protection program, using Metro's habitat inventory. The basin approach proposes using existing Clean Water Services' protection standards coupled with expansion of a capital program to support restoration and volunteer activities. Metro passed a resolution to approve the Tualatin Basin approach as part of the regional program. Metro has agreed to apply the protection and restoration program developed by the Tualatin Basin consortium, if the basin's proposed program meets regional habitat goals.

Urban Ecosystem Research Consortium (UERC). UERC is a consortium of individuals from area academic institutions, public agencies, local governments, nonprofit organizations and other groups interested in advancing the state of the science of urban ecosystems, particularly in the Portland/Vancouver area. Among other activities, UERC sponsors an annual symposium that provides a forum for networking and exchanging information related to urban ecology and its application to natural resource conservation, natural area management, environmental planning, habitat restoration and the social sciences. UERC also has working groups that focus on providing direction and support for urban ecosystem research, creating an information-sharing network for data collection and application, and tracking, housing and providing access to information related to urban ecosystems.

APPENDIX E

The City's Natural Environment

APPENDIX E

The City's Natural Environment

The City's Environmental Setting

General Characteristics

Portland is situated at 20 feet above sea level, near the confluence of the Columbia and Willamette rivers, about 65 miles inland from the Pacific Ocean. It lies midway between the lower Coast Range to the west and the high Cascades Range to the east, each about 30 miles distant. Portland's varied topography includes steep hills, isolated volcanic cones, low rolling hills and extensive flat areas. The area is composed primarily of alluvial deposits and Columbia River basalts. Much of the city is located in the Willamette Valley Plains ecoregion, although steeper portions of the Tualatin Hills on the west side are characteristic of Willamette Valley Hills and Coastal Mountains ecoregions (Clarke and others 1991).

Portland has a mild marine climate that is heavily influenced by the mountain ranges east and west of the city. The Coast Range protects the Portland area from Pacific storms, while the Cascades prevent colder continental air masses from invading western Oregon. In winter, the average temperature is 40°F and the average minimum temperature is 34°F. In summer the average temperature is 65°F with an average daily maximum of 74 to 78°F (Rockey 2002).

The Cascades also lift moisture-laden westerly winds from the Pacific, driving local rainfall patterns. Average annual rainfall in the Portland area is approximately 37 inches. Nearly 90 percent of the annual rainfall occurs from October through May. Only 9 percent of the annual rainfall occurs between June and September, with 3 percent in July and August. Precipitation falls predominantly as rain, with an average of only five days per year recording measurable snow.

The City of Portland's estimated 2000 population was nearly 530,000, and the City's population is expected to be approximately 589,000 by 2017. Land uses in the Portland area include industrial, commercial, low- and high-density residential and open space.

Portland's Watersheds and Waterways and Their Current Conditions

A number of tributaries to the Willamette River pass through the City of Portland, including Johnson Creek, Tryon Creek, Fanno Creek (via the Tualatin River), and a series of small tributaries draining the Tualatin Hills and Forest Park. In addition, the Columbia and Willamette River confluence area (including the Columbia Slough) lies within the City. A general overview of existing conditions within these watersheds is provided below. Detailed watershed characterizations were completed as part of the watershed management process (watershed characterizations are described in Chapter 3 of the *Framework*). The City's watersheds are depicted in Figure E-1 and described in the following sections. Additional information on Portland's watersheds can be found at http://www.portlandonline.com/bes.

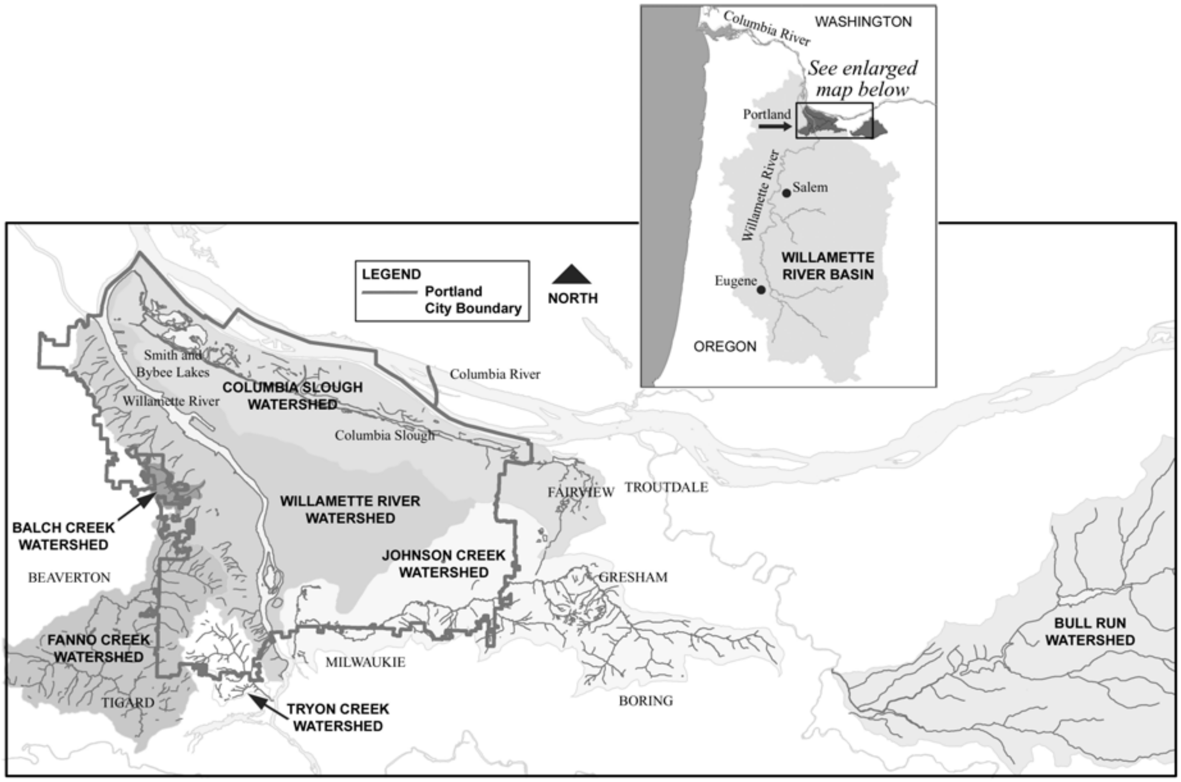

FIGURE E-1
City of Portland Watersheds

Lower Columbia River

The Columbia River is the second largest river in the contiguous United States in terms of stream flow. Land uses within the lower Columbia River watershed are urban/industrial, residential and rural/agricultural. Many of the region's heaviest industrial users are present in the lower Columbia watershed. Land uses in the basin upstream of Portland include timber production, grazing, irrigated and dryland agricultural and urban areas. The lower Columbia watershed has been heavily urbanized and industrialized in the vicinity of Portland for decades and has had many point source and nonpoint source pollution problems. The south bank of the Columbia River in this area of Portland is moderately urbanized. The banks are a mixture of steep natural cobble and sandbanks and riprap; riparian vegetation is generally sparse to absent and consists mostly of invasive plants and shrubs. The south bank of the Columbia River between North Portland Road on the west and the Sandy River on the east acts as a primary levee for flood control. The levee, located under and adjacent to NE Marine Drive, is managed by the Multnomah County Drainage District.

The lower Columbia watershed is degraded relative to historical conditions. River flow in the project area has been significantly altered from historical conditions as a result of the upstream storage reservoir releases and hydropower operations. The channel and broader floodplain has been diked and dredged, and steep, riprapped shorelines along the river have reduced growth of riparian areas and recruitment of large wood (that is, wood deposited through natural processes). Most of the historical off-channel habitats (side channels, oxbow lakes and marshes) have long since been cut off from the channel and filled. Silt and sand dominate the river substrate.

Water quality in the lower Columbia River is fair to poor in summer. Mainstem temperatures often exceed 20°C (68°F), and maximum temperatures can reach 26°C (79°F). The Oregon Department of Environmental Quality (DEQ) has listed the lower Columbia River, from the Willamette to the Bonneville Dam, as water quality limited for total dissolved gases and arsenic under the 303(d) process. This reach was also listed as water quality limited for temperature (summer), pH (spring) and toxics (tissue PCB and DDE, DDT).

The current biological conditions in the lower Columbia River have been degraded as a result of extensive changes in flow, habitat and water quality. Many nonnative fish species have been introduced into the Columbia Basin. This has resulted in increased competition and extirpation (that is, local extinction) of some native species and reduction of the biotic integrity of the system.

Lower Willamette River

The Willamette River is a tributary to the Columbia River at approximately river kilometer (Rkm) 164 (river mile [RM] 102). It is the 10th largest river in the contiguous United States in terms of streamflow. The Willamette Basin is 11,460 square miles in size and constitutes 12 percent of the land area of Oregon (Willamette Restoration Initiative 1999). In 1990, about 70 percent of Oregon's population lived in the Willamette Basin. The Willamette Basin is divided into 12 subbasins. The lower reach of the Willamette—the subbasin that includes the City of Portland—extends from the mouth upstream to the Willamette Falls at Oregon City (RM 26.5, Rkm 42 of the Willamette River).

Land uses within the lower Willamette River watershed in the vicinity of Portland and its suburbs are urban/industrial, residential and rural/agricultural. Many of the state's heaviest industrial users are present in the lower Willamette watershed. Land uses in the basin upstream of Portland include timber production, grazing, irrigated and dryland agricultural and urban areas.

The lower Willamette watershed has been heavily urbanized and industrialized for decades. Within the Portland downtown and harbor areas, the river's banks are typically steep and are primarily composed of bank stabilization and fill materials such as sheet pile, riprap, seawall and concrete fill. Riparian vegetation is generally sparse to absent and frequently consists of nonnative plants and shrubs.

The lower Willamette watershed is heavily degraded relative to historical conditions. Historically, the Willamette River in the Portland area comprised an extensive and interconnected system of river channels, open slack waters, emergent wetlands, riparian forest and adjacent upland forests on hill slopes and Missoula Flood terraces. Connectivity of habitat was high both longitudinally along the river and laterally from the vegetated riverbanks to the upland forests.

Gradually, habitats along the Willamette River have been destroyed, degraded or disconnected through construction of dams throughout the Willamette and Columbia rivers and from fill and development along the Willamette River shoreline and floodplain areas. Large expanses of black cottonwood/Pacific willow forest and spirea/willow wetland have been filled and developed, leaving small strips of riparian forest, wetland and associated upland forests. These remnants are few or entirely lacking for large reaches through the downtown and industrial segments of the river. Most of the historical off-channel habitats (such as side channels, oxbow lakes and marshes) have long since been cut off from the channel and filled. Connectivity and maintenance of these habitats have been reduced or eliminated as a result of marked alteration of the seasonal hydrograph[1], particularly dramatic reduction of peak flows during wet weather months. Connection of many tributary habitats to the mainstem is eliminated or reduced by culverts.

The channel has been diked and dredged throughout the Portland Harbor. The channelized characteristics of the Portland Harbor and surrounding area have adversely modified the habitat types and the localized flow regime. The urban setting minimizes the presence of riparian vegetation and the input of new large wood from riparian areas.

A few small areas of higher quality habitat remain within the highly urbanized reaches of the Willamette. Remnant habitats of high quality—or with the potential to provide important ecological functions if reconnected or restored—include Powers Marine Park, Ross Island, lower Stephens Creek, Tryon Creek, Oaks Bottom, Willamette Park, Kelley Point Park, the Forest Park watersheds and Smith and Bybee wetlands. In addition, natural areas along the Willamette River shoreline provide opportunities to restore lost floodplain and riparian wetland habitats.

Water quality in the lower Willamette River is fair to poor. In 2000, the Portland Harbor was placed on the National Priorities List ("Superfund") for elevated levels of DDT, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and heavy metals. The Lower Willamette River is listed on the 303(d) list for temperature, bacteria, biological criteria (fish skeletal deformities) and toxics (mercury; arsenic and pentachlorophenol near the McCormick and Baxter site). DEQ also identified lead and copper as potential water quality concerns in a 1997 analysis (Oregon Department of Environmental Quality 1997). These parameters are being investigated further to evaluate whether they should be included on the 303(d) list, using ultra-clean sampling and analysis methods and improved detection limits.

The aquatic biota of the lower Willamette River has changed significantly from historical conditions. Extirpations of sensitive species have occurred, and introductions of nonnative species have resulted in increased competition for food and habitat for native species. The existing fish community in the lower Willamette River consists of warm-water, cool-water and cold-water fish. There are several listed salmonid evolutionarily significant units (ESUs) that use the lower Willamette River. At least 33 other native and introduced species of both warm-water and cool-water fish inhabit the river (Oregon Department of Fish and Wildlife 1994).

Johnson Creek

Johnson Creek originates in the hills east of Portland and flows westward approximately 25 miles to its confluence with the Willamette River. The stream receives water from several major tributaries, including Crystal Springs Creek, Kelley Creek, Mitchell Creek, Butler Creek, Hogan Creek, Sunshine Creek and Badger Creek. Land use in the 34,560-acre Johnson Creek watershed ranges from heavily developed urban areas (the cities of Portland, Milwaukie and Gresham) to rural farm and nursery lands (headwaters).

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[1] A hydrograph is the annual and seasonal trend in flow in a stream or river.

Flow monitoring indicates that low-flow conditions in Johnson Creek may adversely impact aquatic life. The Oregon Department of Fish and Wildlife (ODFW) has set minimum flow targets to protect salmonids in Johnson Creek (Meross 2000). Flows in the middle and upper watershed frequently do not meet those minimum flows, particularly in spring and summer months. Below Crystal Springs, which provides consistent and abundant groundwater flows, minimum instream flows are typically met.

There is also evidence of adverse impacts from excessive peak flows. The Sycamore gage provides the longest period of record with which to evaluate changes in flow over time that result from human activities.[2] Statistical evaluation of flow since 1940 indicates some increase in the flashiness of peak flows over the period of record (Clark 1999). Significant impacts on peak flows in Johnson Creek also appear to be affected by alterations in the stream channel and floodplain that change the way floods flow through Johnson Creek, as described below.

Johnson Creek has been substantially altered from its historical configuration. Diking, channelization and other alterations of the natural floodplain have eliminated many of the areas that once absorbed and conveyed floods through the watershed. One of the most significant alterations occurred in the 1930s when the Works Progress Administration widened, deepened, rock-lined and channelized 15 miles of the 25-mile stream in an attempt to control flooding. These alterations have had long-lasting and marked effects on the habitat and hydrology of the watershed. Most significantly, the historical floodplain of Johnson Creek is disconnected or minimally connected through much of the stream's length. The lack of floodplain connection means that flood flows cannot spread out and attenuate on the floodplain. Instead they are directed and concentrated into the main channel, where they increase scour and degrade instream habitat.

ODFW conducted habitat surveys throughout Johnson Creek (Oregon Department of Fish and Wildlife 2000). The department's findings indicate that Johnson Creek has extremely low wood volumes, a high percentage of hardened banks, lack of refugia through many reaches, channel incision and high levels of fine sediment. Riparian vegetation is minimal or lacking throughout much of the watershed. Interestingly, riparian vegetation is as lacking in the upper watershed as it is in the lower watershed.

Fish access to tributary habitat is impaired by culverts throughout the watershed. Although there are no culverts on the mainstem until high in the watershed, they are present on nearly all the tributaries to Johnson Creek. Crystal Springs, an area used by resident and migratory Willamette Basin salmonids, has a series of partially impassable culverts along its length, and some of the least developed tributaries along the southern side of the middle watershed also have culverts along their confluences with the mainstem.

Water quality in Johnson Creek is rated as fair to poor. Johnson Creek was placed on the 303(d) list by DEQ for bacteria, summer temperature and toxics (DDT and dieldrin). The 303(d) listing includes the entire stream, from the mouth to headwaters. The numerous investigations of temperature in Johnson Creek over the years have consistently indicated that elevated temperatures are a problem throughout the watershed.

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[2] The Sycamore gage is above the City of Portland and so does not reflect the impacts from the most intensely urbanized portion of the watershed. However, it does reflect impacts from Gresham and other changes within the middle and upper watershed since the 1940s.

The fish community in Johnson Creek is dominated by native redside shiners, reticulate sculpin and speckled dace (Johnson Creek Corridor Committee 1995). Largescale suckers are abundant in the lower reaches. Adult salmonids that have been observed in the stream include coho salmon, Chinook salmon, cutthroat trout and steelhead (ODFW unpublished data, as cited in Ellis 1994; C. Smith, City of Portland, personal communication, 2005).

Tryon Creek

Tryon Creek is a seven-mile free-flowing stream located in a 4,237-acre watershed. The stream flows in a southeasterly direction from the West Hills of Portland to the Willamette River near Lake Oswego. It is primarily a low gradient stream with steep hillslopes. The upper watershed has undergone common impacts associated with urban development, including increased stream velocities and stream bank erosion (City of Portland Bureau of Environmental Services 1997). The increased impervious surface in the upper watershed has resulted in higher volume peak flows during wet weather months, and low summer base flows.

Channel condition is typical of a moderate-gradient Cascade stream with steep slopes. Approximately 60 to 75 percent of the slopes within the watershed exceed a 30 percent grade (City of Portland Bureau of Environmental Services 1997). This results in a high frequency of mass wasting and erosion. In addition, soils in the watershed are from a silt loam series (Cascade) that are underlain by a fragipan[3] that impedes water infiltration and root penetration. This results in a high incidence of wind throw, mass wasting, channel incision and bank erosion.

Historically, Tryon Creek provided habitat for sea-run cutthroat, steelhead, and coho salmon. However, development activities, particularly culvert and road crossings, have resulted in degraded habitat and migration barriers. Habitat in Tryon Creek has been evaluated in ODFW stream surveys (Oregon Department of Fish and Wildlife 2000) and a City of Portland corridor assessment (City of Portland Bureau of Environmental Services 1997). Instream habitat ranged from marginal to optimal in a few areas, with most of the marginal habitat within the more heavily urbanized upper watershed. Highest quality habitats were located within Tryon Creek State Natural Area and Oregon State Parks, which had wide and relatively undisturbed riparian, floodplain and upland buffers. Even within this protected area, however, wood volume was low and channel incision was evident. Above the park the stream becomes highly segmented by road crossings and their associated culverts, and it is affected by intensive urban development.

Arnold Creek, one of the larger tributaries to Tryon, has good instream habitat within the lower section, with suboptimal percentages of fines, bank erosion and incision being the primary forms of degradation within the lower reaches. However, Arnold Creek is highly segmented by culverts from road and driveway crossings. In addition, invasions of nonnative plants are evident even within the higher quality areas of Arnold Creek and Tryon Creek State Park. Falling Creek, another major tributary to Tryon, has poor to marginal instream habitat, with a lack of instream cover, poor bank and riparian structure and excessive fine sediments.

[3] A soil layer, often composed of clays, that can act to slow or impede infiltration of water.

Water quality in Tryon Creek is good to fair. Tryon Creek is on the DEQ 303(d) list for summer temperature. An examination of the data indicates that with the exception of temperature and bacteria, water quality generally meets water quality standards.

Impairment of fish access to habitat by culverts is a significant issue throughout the Tryon Creek watershed. A large culvert is present at the mouth of Tryon Creek just above its confluence with the Willamette River (at RM 19.9). Although baffles are present within this culvert, it is likely that the culvert impairs salmonid movements into and out of the watershed. An impassable culvert is present at Boones Ferry Road. Above this, there are many additional impassable culverts on Tryon and Arnold creeks that limit movements of resident fish through the watershed. A series of waterfalls and rapids at Marshall Park (at RM 2.7) would have naturally limited anadromous fish access prior to the presence of culverts, except during high flows.

Fanno Creek

Fanno Creek is a tributary to the Tualatin River Basin, which drains about 20,500 acres (City of Portland Bureau of Environmental Services 1997). Land use in Fanno Creek is dominated by residential and commercial activities. Impervious areas, which are connected to a stormwater drainage system, make up 28 percent of the watershed, and 12 percent of the watershed consists of impervious areas that are not connected to the storm drain system.

Instream habitat quality in Fanno Creek and in two tributaries—Vermont and Woods creeks—was rated as extremely impaired or threatened, primarily as a result of adverse effects from excessive amounts of fine sediment (City of Portland Bureau of Environmental Services 1997). High channel erosion is present through much of the watershed within the city as a result of lack of bank vegetation, large wood and rock. These factors result in limited habitat complexity and instream cover. Channel morphology is generally poor and dominated by pools or glides with very few riffle areas. Isolated areas with comparably higher habitat values are present in some reaches in relatively undeveloped areas, headwater reaches, and at tributary confluence areas.

As a tributary to the Tualatin River, Fanno Creek has total maximum daily loads (TMDLs) for temperature, total phosphorus, dissolved oxygen and bacteria. Urban and suburban development within the watershed has contributed to these water quality problems as a result of reduced riparian vegetation and increased nutrient loading and stream temperatures.

Most of Fanno Creek within the City of Portland is currently inaccessible to anadromous fish because of impassable culverts downstream of City limits. However, anadromous steelhead and coho salmon likely historically used upper Fanno Creek for spawning and rearing, and could potentially in the future with fish passage improvements through mainstem habitats. The City of Portland sampled fish populations in 1993 and found reticulate sculpin, redshide shiner, cutthroat trout and peamouth present in the upper reaches.

Forest Park Streams (Balch Creek, Miller Creek and Other Tributaries)

The Forest Park streams contain a number of small watersheds such as Balch and Miller creeks. Land use within these subbasins is largely open space, although there are also residential, industrial and transportation uses.

Because of the extensive protection provided by Forest Park, the Forest Park watersheds are probably among the least altered watersheds within Portland when compared with their historical conditions. The exception to this is in the lower reaches, where each stream must pass under Highway 30 and through the heavily industrialized port and industrial areas along the banks of the Willamette. The streams typically pass through pipes for considerable lengths through this section and receive stormwater and combined sewer overflow discharges before discharging to the Willamette.

The hydrographs in these small watersheds are probably reasonably comparable to historical conditions because of the low overall percentages of imperviousness and small amounts of stormwater drainage to them. Channel conditions range from mature forested stands with good bank stability in the middle and upper sections to underground pipes that carry the streamflow through industrial areas and then out to the Willamette River via a pipe outlet in the lower sections.

Limited water quality data are available for these streams. Based on our knowledge of these streams, water quality is probably generally good, except in the lower sections, which receive stormwater and CSO discharges. Excessive amounts of fine sediment may occur in sections of these streams near residential or industrial development. Summer temperatures may be unsuitable in certain areas, as a result of reduced and unvegetated riparian areas. Toxic contamination may be an issue in reaches receiving CSO and stormwater discharges.

The biota of the Forest Park streams are likely altered relative to historical conditions. The piping of streams and installation of culverts have blocked habitat access for anadromous fish; this has resulted in the extirpation of native anadromous fish species. Resident cutthroat trout are still present in many of these watersheds.

Columbia Slough

The Columbia Slough extends 18 miles from Fairview Lake on the east to the Willamette River at Kelley Point Park on the west. The slough drains 51 square miles, or 33,000 acres, of residential neighborhoods, commercial and industrial areas, open space and transportation corridors. The Columbia Slough is the remnant system of marshes, wetlands, lakes and side channels that historically formed the floodplain of the Columbia River between the mouths of the Willamette and Sandy rivers. However, the Columbia Slough has been severely altered from this historical condition. About half of the waterway is now a highly managed water conveyance system with dikes and pumps that provide watershed drainage and flood control and maintain a highly artificial hydrograph. Over the years extensive urban, agricultural and industrial development have profoundly altered the watershed and have resulted in a contaminated watershed that has lost a vast percentage of its upland, wetland and aquatic habitat.

The slough's channel configuration and flow regime have been altered significantly from historical conditions. Large amounts of open water areas and wetlands have been eliminated as a result of urban development, and the hydrologic connectivity of the entire system has been greatly reduced. The creation of the levee on which Marine Drive is located has blocked the direct connection between the Columbia Slough and the Columbia River system. A levee and pump station at NE 18th Avenue blocks passage of fish into the upper parts of the slough.

Consequently, juvenile salmonids from the lower Willamette River that are seeking out rearing habitats have access only to the lower section of the slough and Smith and Bybee wetlands.

Water quality in the Columbia Slough watershed is highly degraded. DEQ has placed the Columbia Slough on the 303(d) list for 10 parameters (four toxics, bacteria, nutrients, pH, dissolved oxygen, chlorophyll *a* and temperature).

The biological communities in the Columbia Slough are degraded as a result of the extensive degradation of flow, habitat and water quality conditions. Though heavily altered, these habitats continue to provide stopover, wintering and nesting habitat for over 200 bird species, including nesting bald eagles, great blue heron rookeries, and a number of other sensitive species. Fish communities are dominated by nonnative warm-water fish species such as common carp and bluegill although the Lower Columbia Slough and Smith and Bybee wetlands continue to provide important rearing and refuge habitat for juvenile steelhead, coho and Chinook salmon. All three native freshwater mussel species (*Anadonta* sp.) have been documented in the Columbia Slough and Smith and Bybee wetlands. Benthic macroinvertebrate communities are extremely sparse.

Biological Communities and Habitats in the City

Three broad classes of habitat are present in the Portland area that support fish and wildlife: aquatic, riparian and upland. A fourth habitat type—wetland—can occur in any of these, and therefore is also presented. The type, distribution and quantity of these habitats in Portland's watersheds and waterways are highly variable as a result of the diversity of environmental factors (topography, soils, geomorphology, climate, vegetation, etc.) and human-related factors (land use activities, habitat disturbance, etc.).

Habitat attributes can be used as valuable indicators of the composition and condition of the biological community. For example, the composition of biological communities can be tied in very predictable fashion to their preferred habitat associations. The health of biological communities is directly affected by the types and condition of specific habitat features. For example, salmonids prefer not only cold, clean and clear water but also specific physical habitat features, such as a diversity of depths, velocities and substrates.

Aquatic Habitats

Aquatic habitats can be broadly classified as running-water or slack-water systems. In the mainstem Columbia and Willamette rivers running-water habitats and the processes that form them differ substantially from running-water habitats in the much smaller tributaries. More than size and flow volume distinguish large, low-gradient streams from small tributaries. Elements such as flood frequency, channel characteristics, disturbance regimes and productivity all vary, creating unique habitats.

Floods are a driving force in large rivers such as the Columbia and Willamette. In these rivers, floods are often slow to rise, extensive and can last for several months, but they generally occur during predictable seasons. Plants and animals found in the floodplain environment have responded to this regime of predictable flooding by developing adaptations suited to the wetter location. In contrast, smaller tributaries tend to have irregular flood patterns that are strongly influenced by local precipitation events.

Tributary streams generally have smaller channels and narrower floodplains. The channel and the floodplain, when there is one, consist of larger rocks and boulders and poorly sorted gravels (Gurnell 1995). Pools, riffles and glides are common habitat features. Wood may be large enough to span the channel and is not easily dislodged in headwater streams. Where tributaries are wide enough and have flow volume that allows the downstream movement of logs and stumps, logs can accumulate in jams spaced several channel-widths apart. In large, low-gradient streams, sediments are sorted by size and generally include abundant fine particles of silt and clay. The pool, riffle and glide sequence common in the tributary streams is no longer the dominant feature of the habitat. Instead, channel roughness, shallow-water areas and deep pools define aquatic habitats. Logjams are scattered along the shoreline near the high-water line, at the end of islands and bars and submerged in the channel.

Disturbance regimes also can differ. In tributary streams, the more direct contact between the river and adjacent hillsides results in more frequent landslides, debris flows, dam-break floods and bank erosion. In turn, channel form is more likely to be influenced by mass wasting and alluvial processes (Naiman and others 1992). However, mass wasting is less common along large rivers because the river's terraces and floodplains generally insulate adjacent hillsides from the river's erosive forces. However, floods, tree falls and bank erosion are common forms of disturbance along large rivers.

Tributary streams typically have narrow tree canopy openings, which reduce the amount sunlight reaching the stream. In headwater streams as little as 1 to 3 percent of the total available solar radiation reaches the stream. This reduced sunlight helps maintain relatively cool and stable daily temperatures (Naiman and others 1992). As stream size increases, solar input increases. For large rivers, most of the solar input reaches the river, although penetration can be limited by river depth.

The amount of sunlight reaching large river waters supports the production of phytoplankton, periphyton and rooted vascular plants that are dominant in large river food webs. Fine particulate matter from upstream and from floodplains also plays a critical role in supporting the tropic structure of large river aquatic communities. Zooplankton and benthic detritivores are considered important invertebrate consumers. However, floodplain inundation is critical to providing the organic inputs necessary to support productivity. In smaller tributary streams primary production is lower. Invertebrates consume algae or organic material derived from riparian vegetation.

Riparian Habitats

Riparian areas are the environments adjacent to streams and rivers, a zone of direct interaction between terrestrial and aquatic ecosystems. An intact riparian area serves a multitude of functions vital to aquatic ecosystem health. More specifically, a healthy riparian and aquatic ecosystem provides the functions discussed below.

Organic Materials. Riparian vegetation influences adjacent aquatic systems by providing important components of the food web (Hachmoller and others 1991, Forest Ecosystem Management Assessment Team 1993), and it plays a significant role in the structure of aquatic communities. Litterfall, such as leaves, twigs, bark and needles, can fall to the ground or directly into the stream, providing an important food source for insects and invertebrates.

Channel Dynamics. Stream channels are dynamic systems. Water velocities and levels fluctuate, submerging and exposing the riparian zone and floodplain (Swanson and others 1982) through time. Meanders can slowly shift downstream or across the floodplain as erosion wears at stream banks, or they can migrate suddenly when a flood cuts a new channel that captures the bulk of a stream's flow. Wood entering the stream channel from the riparian area influences channel dynamics by diverting flow, creating channel roughness and stabilizing banks (Forest Ecosystem Management Assessment Team 1993, May and others 1997, Gregory and others 1991, Sedell and others 1988). Such processes help create a variety of habitats in the floodplain and maintain channel complexity. Annual flooding allows for the interchange of organic material and nutrients (in the form of wood, leaf litter and invertebrates) between the riparian and aquatic environments.

Water Quality. The roots, wood and soils in the riparian area contribute to water quality (Forest Ecosystem Management Assessment Team 1993). Roots and wood help limit sediments entering the stream by moderating the erosive power of floodwaters and holding soils in place (Budd and others 1987). Riparian vegetation acts as a barrier that reduces sediment and debris transport (Swanson and others 1982, Gregory and others 1991), slows surface flows and encourages infiltration (Budd and others 1987, Knutson and Naef 1997). Riparian areas also filter (from groundwater and surface flows) sediments (Forest Ecosystem Management Assessment Team 1993), pollutants (Knutson and Naef 1997), metals and excess nutrients (Castelle and others 1994). Riparian vegetation absorbs and stores nutrients and other dissolved materials as they are transported through the riparian zone (Spence and others 1996).

Water Quantity. In a watershed, a variety of characteristics, such as climate, topography, geology, geomorphology and vegetation, all interact to determine the amount and velocity of water flowing in a stream (Spence and others 1996). In riparian areas, and throughout a watershed, water can be stored and transported in the atmosphere, vegetation, stream channel, floodplain, soil and shallow or deep groundwater aquifers. Riparian features and functions are a critical part of this storage and transport system.

Riparian plants intercept, store and transpire water. Water stored in the atmosphere can be intercepted by vegetation or other structures. The leaves, needles and branches in the canopy and on the ground can absorb precipitation and prevent it from reaching the ground, or they slow its progress, thus reducing the amount of erosion and runoff (Black 1990).

Microclimate. The diverse structure and composition of the riparian zone create microclimates, multi-layered canopies and off-channel areas that provide fish and wildlife habitat. Riparian vegetation creates a microclimate that influences both the riparian area and stream environment by affecting soil moisture and temperature, air temperature, water temperature, wind speed and relative humidity (Forest Ecosystem Management Assessment Team 1993).

Wildlife Habitat. Budd and others (1987) claims that, regarding riparian habitat, "there is no other habitat type upon which wildlife is more dependent." This statement is supported by Kauffman and others (2001), who report that although riparian zones cover only an estimated one to two percent of the landscape, 53 percent (319 out of 593) of wildlife species that occur in Oregon and Washington use these areas. The Forest Ecosystem Management Assessment Team (1993) reports that most vertebrates regularly use the riparian zone for some part of their activity and that the zone also provides wet micro-sites, seeps and springs that are important for maintaining arthropods, mollusks, bryophytes, vascular plants and riparian-associated amphibians. Riparian vegetation also is known to influence benthic communities (Erman and others 1977), birds and mammals (Castelle and others 1994, Kauffman and others 2001) and herpetofauna (Kauffman and others 2001).

Intact riparian areas are important to fish and wildlife because they do the following:

- Have a high diversity of vegetation species and structure
- Often have unique vegetation assemblages relative to the upland area
- Exhibit high edge-to-area ratios because of their linear nature
- Influence the environment-microclimate, chemistry, structure
- Provide corridors and migration routes
- Provide habitat features necessary for the survival of many species, including water, forage, nesting and breeding habitat, resting areas and cover (Kauffman and others 2001)

Upland Habitats

Upland habitat refers to all areas that are not riparian, wetland or open water habitats. (It should be noted, however, that wetlands may be found within upland areas). Although most wildlife species associated with upland habitats also use riparian areas, they are dependent on upland areas for key aspects of their life history such as breeding, food or shelter. Habitat types found in upland areas include grassland or meadow, shrubs, coniferous or deciduous forests and rocky slopes.

Johnson and O'Neil (2001) describe five upland habitat types present in significant amounts in the Portland area. These include Westside Lowlands Conifer-Hardwood Forest, Westside Oak and Dry Douglas-fir Forest and Woodlands, Westside Grasslands, Agriculture Pasture and Mixed Environs, and Urban and Mixed Environs. These five make up the majority of upland habitats available to native wildlife in this region. Eighty-nine percent of all terrestrial species in the Portland area are associated with upland habitats, with at least 28 percent depending on these habitats to meet their life history requirements.

Westside Lowlands Conifer-Hardwood Forest

This habitat is widespread and prevalent in the Portland area. Historically and currently the most extensive of all natural habitats west of the Cascade Mountains, it often forms the matrix within which other habitats occur as patches and is very important to wildlife in this region. This habitat may be dominated by conifers, deciduous trees or both and tends to have structurally diverse understories. In nutrient-poor soil conditions evergreen shrubs dominate the understory, while nutrient-rich or moist sites contain more deciduous shrubs, ferns and grasslike plants. Mosses are a major ground cover component, and older stands are rich with lichens.

Several wildlife species dependent on this habitat are at risk at the state and/or federal level. This includes one amphibian, the Northern red-legged frog. At-risk bird species dependent on this habitat include band-tailed pigeon, Northern pygmy-owl and olive-sided flycatcher. Mammals include two bat species (long-legged myotis and silver-haired bat) and a tree-dwelling rodent, the red tree vole.

Westside Oak and Dry Douglas-Fir Forest and Woodlands

This habitat is limited in area and declining in extent and condition in the Willamette Valley. Conifers, deciduous trees or some combination of the two may dominate these typically dry woodlands. Canopy and understory structures are variable, ranging from single- to multi-storied, with large conifers sometimes emerging above deciduous trees in mixed stands. This habitat is too dry for western hemlock and western red cedar; lack of shade-tolerant tree regeneration, along with understory indicators such as tall Oregon grape, help distinguish oak woodlands from Westside Lowlands Coniferous-Hardwood forests. Large woody debris and snags are less abundant than in other westside forested habitats. Sweet cherry (*Prunus avium*) and English hawthorn (*Crataegus monogyna*) have invaded and sometimes dominate this habitat's subcanopy in the Metro region.

Several wildlife species dependent on this habitat are considered at risk at state and/or federal levels. These include band-tailed pigeon, Lewis' woodpecker (extirpated as a breeding species), acorn woodpecker and Western bluebird. At-risk mammals include Western gray squirrel and red tree vole.

Westside Grasslands

Once widespread in the Willamette Valley, Westside Grasslands are now rare and declining because of fire suppression, conversion to agriculture and urban habitats and invasion by nonnative species. In the Metro region, this habitat has virtually disappeared.

Agriculture, Pasture and Mixed Environs

Occurring within a matrix of other habitat types, agricultural lands often dominate the landscape in flat or gently rolling terrain, on well-developed soils and in areas with access to irrigation water. This habitat can be diverse, ranging from hayfields and grazed lands to multiple crop types, including low-stature annual grasses to row crops to mature orchards. Hedges, windbreaks, irrigation ditches and fencerows provide especially important habitat for wildlife (Demers and others 1995). The U.S. Department of Agriculture (USDA) Conservation Reserve Program lands are included in this category and may provide valuable wildlife habitat. Agricultural lands are subject to exposed soils and harvesting at various times during the year and receive regular inputs of fertilizer and pesticides, thus influencing the quality of water-associated habitats.

The greatest conversion of native habitats to agricultural production occurred between 1950 and 1985, primarily as a function of U.S. agricultural policy (Gerard 1995). Since the 1985 Farm Bill and the economic downturn of the early to mid 1980s, the amount of land in agricultural habitat has stabilized and begun to decline (National Research Council 1989). The 1985 and subsequent farm bills contained conservation provisions encouraging farmers to convert agricultural land to native habitats (Gerard 1995, McKenzie and Riley 1995). Clean farming practices and single-product farms have become prevalent since the 1960s, resulting in larger farms and widespread removal of fencerows, field borders, roadsides and shelterbelts (National Research Council 1989, Gerard 1995, McKenzie and Riley 1995). In Oregon, land-use planning laws adopted in 1973 prevent or slow urban encroachment and subdivisions into areas zoned as agriculture.

Twenty-nine percent of birds and 25 percent of mammals native to Oregon use croplands and pasturelands to meet their habitat needs (Puchy and Marshall 1993). Agricultural fields left fallow for the winter often provide wintering habitat for migratory birds (Puchy and Marshall 1993). Many of the species that use this habitat require the nearby associated aquatic habitats to meet their needs. Bird species at risk that depend on this habitat include Oregon vesper sparrow and Western meadowlark. One mammal, the Camas pocket gopher, is at risk at the federal level.

Urban and Mixed Environs

These areas are widely distributed but patchy. Urbanization encompasses all habitats with impervious surfaces covering at least 10 percent of the land's surface (less than 10 percent is considered rural). Characterized by buildings and other structures, impervious surfaces and plantings of nonnative species, urban environments provide habitat to some species requiring structures such as cavities, caves, cliffs and rocky outcrops and ledges. Nonetheless, neighborhood and street trees and vegetation is important for migratory birds and other native animals. This habitat is subdivided into low-density (10 to 29 percent impervious surfaces), medium-density (30 to 59 percent impervious) and high-density (60+ percent impervious) areas, described in detail in Johnson and O'Neil (2001). Many human-induced changes in urban areas are essentially irreversible; for example, building a house requires removing vegetation, scraping and leveling topsoil, building driveways and roads and running sewers and utilities both above and underground. Canopy cover is reduced in these habitats, and structural features present in historical vegetation, such as snags and dead wood, are rare.

Frequent human disturbance is normal in urban habitats, and species that are disturbance-sensitive tend to be absent or reduced in numbers (Marzluff and others 1998). Historical natural disturbance patterns are largely absent in urban habitats, although flooding, ice, wind or fire still occur. Flooding and pollution are more frequent and more severe in areas with significant impervious surface cover and/or modified stream systems. Temperatures are elevated, background lighting is increased and wind velocities are altered by the urban landscape (often they are reduced, except around the tallest structures downtown, where high-velocity winds are funneled around the skyscrapers). Urban development often occurs in areas with little or no slope and frequently includes wetland habitats. The urban and mixed environs habitat type is expected to increase at an accelerating pace locally and nationally (Parlange 1998).

Studies in the Pacific Northwest document declining wildlife diversity with increasing urbanization (Penland 1984, Puchy and Marshall 1993). Nonnative species and generalists are most common in urban habitats. Few sensitive species are associated with this habitat, because sensitive species are often habitat specialists that are quickly out-competed by nonnatives and generalists. The only closely associated mammal of concern is big brown bat (*Eptesicus fuscus*), also known by the common name "house bat." This nonmigratory species often lives in a variety of artificial structures, eating termites and beetles (Csuti and others 1997).

Artificial structures provide key habitat for some wildlife species in the urban area (Puchy and Marshall 1993). For example, bridges provide important bat habitat. Fences, power lines and poles provide perches from which hawks and falcons search for prey. Ledges of several tall buildings in the urban area provide perching sites for wintering peregrines, from which they can chase prey (Puchy, personal communication, 2001). Nest boxes and bird feeders provide valuable resources, as the continuing recovery of western bluebirds within the Metro area demonstrates. Chapman Elementary School in Portland is renowned for the annual roosting of thousands of Vaux's swifts in the furnace chimney, and the school community is working to conserve these long-distance migrants (Robertson 1999). Since 1993 peregrine falcons have chosen the Fremont Bridge, the St. Johns Bridge and other structures in the Portland area as a nesting place, as these structures have characteristics similar to the high cliffs that would be attractive in the wild (Sallinger 2000; Puchy, personal communication, 2001). The bridges provide two important functions for the peregrine falcons: a high nesting spot inaccessible to humans and proximity to a constant food supply, in the form of nonnative pigeons, starlings and other birds.

There are no species at risk dependent upon this habitat, although the purple martin population in Portland appears to be dependent on artificial nest boxes along Marine Drive (Puchy, personal communication, 2004).

Wetland Habitats

Wetlands can occur in aquatic, riparian and upland areas, and play important roles in watershed health. Key wetland functions are described below.

Streamflow, water storage and watershed hydrology. Wetlands are of major importance to watershed hydrology. Riparian wetlands intercept surface and subsurface (groundwater) runoff from the upland regions of the watershed, and thus function as buffers for the river systems. Riparian wetlands found in low-lying areas adjacent to rivers and streams are periodically subject to overbank flooding and can provide important seasonal storage and flood control functions (Debusk, 1999; Adamus et al., 2002). Wetlands function like sponges, storing floodwater, surface water or groundwater, and slowly releasing it (Arkansas Multi-Agency Wetland Planning Team, 2001). How riparian wetlands interact with groundwater and floodwaters, can vary considerably depending on their geomorphology, e.g., located in headwater areas, riparian slopes, floodplains, etc. (Cole et al., 1997). Upland wetlands formed by depressions in the landscape my be isolated from stream and rivers and can have a lesser role in the surface hydrology of the watershed (DeBusk, 1999). However, isolated wetlands commonly are integral parts of extensive groundwater flow systems, and isolated wetlands can spill over their surface water divides into adjacent surface water bodies during periods of abundant precipitation and high water levels (Winter, T. and LaBaugh, J.W., 2003).

Bank stabilization and sediment, pollution and nutrient control. Wetlands play an important role in maintaining water quality. When wetlands reduce flows and velocity of floodwaters, they reduce erosion and allow floodwaters to drop their sediment (CA Dept. of Water Resources 2000). Chemicals and nutrients can enter a wetland through surface water and sediment, or through groundwater. Riparian wetlands have been shown to be highly effective in the reduction of non-point source (NPS) loading of nutrients and sediments to rivers and streams. The physical and biogeochemical processes that occur in wetlands provide a natural filtering mechanism in the watershed to maintain or enhance downstream water quality (Debusk 1999). Nutrients such as nitrogen and phosphorus are transferred from water to sediment, wetland plants or atmosphere (Arkansas Multi-Agency Wetland Planning Team 2001). Wetlands can also help to decompose organic waste materials and heavy metals. Of particular significance to downstream water quality are riparian wetlands associated with low-order (smaller) streams, because of the large hydrologic throughput in these wetlands relative to the flow in the river or stream. These wetlands generally occur in the upper reaches of watersheds (DeBusk, 1999).

Channel dynamics. Wetlands help contribute to channel dynamics by moderating flood flows that can cause scour or channel down-cutting. Wetlands also help stabilize the banks of drainageways, creeks and small streams, and seeps and springs, reducing erosion and sedimentation in adjacent waters. Wetlands protect banks from erosion by absorbing and dissipating the impact of waves and fast flowing, running water (Metro 1998). Floodplain and riparian wetlands can also contribute to channel complexity and provide fish and wildlife access to off-channel habitats (Adamus et al., 2002).

Organic inputs, food web, and nutrient cycling. The production, accumulation, dispersal, and decay of plant material in appropriate amounts and at appropriate times of the year are essential to maintaining healthy aquatic food webs. Because of their high productivity, wetlands provide essential food chain support (Mannix and Morlan for the Woodland Fish and Wildlife Project, 1994). Floodplain wetlands are often productive because nutrients are regularly cycled through the system by floodwaters, discharging groundwater, and extensive ecotones between oxic and anoxic sediments (Adamus et al., 2002).

Microclimate. Wetlands help maintain the local microclimate. Evapotranspiration from wetlands maintains local humidity and rainfall levels. Vegetation in and surrounding wetlands can help maintain the microclimate at the wetland edge, a factor particularly important in small wetlands (British Columbia Ministry of Forest Research Program 2000). Vegetation removal in or around a wetland can result in changes to local microclimate (Mannix, R. and Morlan, J. for the Woodland Fish and Wildlife Project, 1994).

Habitat. Wetlands provide food in abundance, water, refuge from summer heat, shelter from winter cold, hiding cover, late summer green forage when upland areas are dry, and critical breeding and rearing habitats (Mannix and Morlan for the Woodland Fish and Wildlife Project, 1994). Wetlands provide important habitat for a variety of species, including resident and migratory birds (e.g., swallows, flycatchers, waterfowl and shorebirds); mammals (e.g., bats, ungulates, and beavers); amphibians (e.g., salamanders and frogs); as well as important plant species such as cattails, sedges, rushes, pond lilies and willows (Missoula County, 1999).

Salmonid Use of the Lower Willamette River Basin and Portland's Waterways

Adult Chinook, coho and steelhead migrate through the lower Willamette River to reach spawning areas in the Clackamas River and the middle and upper reaches of the Willamette River Basin. In addition, fry, subyearling and yearling salmon rear and reside in available habitats of the lower Willamette River. Because the lower Willamette River is the only migratory route for adult and juvenile salmonids, habitat quantity and quality (and environmental condition) through the lower river prominently affects pre-spawn survival, spawning success; juvenile growth and survival; and ultimately potential population productivity of Willamette Basin salmonids.

Below is a brief description of Willamette River Basin salmon and their use of the lower Willamette River basin, including mainstem and tributary use.

Chinook Salmon (*Onchorynchus tshawytscha*)

Juvenile Migration. Recent studies through the lower, middle and upper Willamette Basin show that juvenile Chinook express complex life history traits (Cramer 1996; ODFW 2005; Schroeder et al. 2003). For example, ODFW staff biologists (Schroeder et al. 2003) have documented three distinct migration patterns in McKenzie River spring Chinook: 1) age-0 fry that migrate in late winter through early spring, 2) age-0 subyearlings that migrate in late winter through early spring, and 3) yearling smolts that migrate in early spring. These documented life history traits are similar to those observed in the 1950's and 1960's (Mattson 1962, Mattson 1963, Craig and Townsend 1946).

Four consecutive years of fish monitoring and research (below Willamette Falls) confirm the presence of large numbers of subyearling Chinook salmon using mainstem habitats for a greater portion of the year (ODFW 2005), particularly from November through June and July. Data likewise show that yearling Chinook travel quickly through the lower river (median migration rate = 12.4 km/day and residence time = 2.4 days), coincident with increasing river flows and increasing body size (or forklength). Baker and Miranda (2003) note that subyearling Chinook enter Multnomah Channel and the lower Columbia Slough from January through June, with peaks in February, and Portland General Electric staff observe Chinook fry and juveniles passing the Willamette Falls (Sullivan Plan) during high flow events (Reed 2004). In addition to mainstem use, juvenile Chinook have been documented in lower tributary reaches of Johnson Creek and Crystal Springs Creek (Ellis 1994, Reed and Smith 2000) and have been documented in the lower Columbia Slough and Smith and Bybee Lakes (Fishman Environmental Services 1987). The combination of these studies confirms the Independent Scientific Group's (2000) belief that juveniles move from upriver tributary sites into mainstem habitats to rear and over winter before migrating to the ocean (Healey 1991).

Juvenile Feeding and Growth. Salmonid diet studies in large, low gradient rivers, such as the lower Willamette River are scarce. In the early 1960's, Mattson analyzed scales of returning adult Chinook salmon to evaluate relative growth patterns during freshwater rearing. Mattson (1962) concluded that growth rates of fry and subyearling Chinook that reared in the lower Willamette River (near Lake Oswego) exceeded freshwater growth rates of yearling migrants that remained in the upper Willamette tributaries such as the McKenzie, Middle Fork Willamette and Santiam rivers. Mattson (1962) further concluded that the small number of yearling spring migrants experienced superior freshwater growth in the lower Willamette River. Howell et al. (1985) found similar results, noting that juveniles rearing in the lower mainstem Willamette had an accelerated growth pattern and emigrated seaward up to two months earlier than juveniles emigrating from upper Willamette Basin tributaries.

Recent studies completed by ODFW suggest similar findings. From 2000 through 2004, ODFW (2005) analyzed the diet and growth rate of juvenile Chinook in the lower Willamette River, specifically from Willamette Falls to the confluence with the Columbia River. They found that migrating yearling Chinook extensively feed in the lower Willamette River. Baker and Miranda (2003) likewise documented subyearling growth during residence in the lower Columbia Slough, Smith and Bybee Lakes and in several locations of Multnomah Channel from January through June. Diet analysis show that daphnia are a dominant food item (comprising 91% of the food items in the samples collected) and comprise a significant proportion of dietary intake (43% of the weight) throughout most of the year. The compilation of recent studies confirms what Mattson (1963), Howell (1988) and others concluded nearly 50 years before – the lower Willamette River is valuable rearing habitat.

Adult Migration. Willamette Basin spring Chinook are an early-run population and are believed to be relatively isolated from other Columbia Basin spring Chinook salmon. As early as 1903, Oregon state fish biologists noted that Willamette River salmon were an early-run fish that enter the Columbia River basin early in the season in order to navigate above Willamette Falls and get up into remote areas of the upper Willamette River (and its tributaries) (Department of Fisheries 1905). The majority of Willamette River spring Chinook historically matured in their fourth and fifth year, with five year olds comprising the largest portion of the run. Today, spring Chinook enter the Willamette at age three to five from April through June.

Adult migrations generally coincided with periods of high rainfall or snowmelt and with warmer temperatures. This relationship between flow and run-timing of Willamette Basin Chinook has long been recognized by fishery biologists. Adult spring Chinook enter the lower Columbia and Willamette Rivers beginning in February and ascend Willamette Falls in April and May (with peak migrations from mid to late May) (Myers 2003, Wilkes 1845). Depending on weather patterns and the river state, migration timing may vary. In recent past, spring Chinook have ascended the falls beginning in March, with peak passage in May, and the majority of adults passing in April and May (Firman et al. 2005).

Although a large portion of the spring run passed and occupied reaches above the falls, historic records show that a run of spring Chinook entered the Clackamas subbasin in March, prior to the upper Willamette fish run. The upper Clackamas basin was historically very productive for spring Chinook salmon. Oregon Department of Fisheries (1903) reported that, "the Clackamas River is, as has always been conceded, the greatest salmon breeding stream of the water that our state affords". Important areas included the upper mainstem river and the Collawash River, particularly the Big Bottom area. The Clackamas River run historically entered the river in March and April, and sometimes as early as February (Barin 1886). Today, adults enter the upper Clackamas basin from May through July, with peak spawning in October.

Adult Spawning. Adult spring Chinook migrate slowly upstream, holding in deep pools (0.10-m to 10-m) through the summer (Chapman, 1943; and Briggs, 1953), then spawn in mid- to upper river reaches in late summer and fall (between August and November). Spawning generally begins in late August or early September (but sometimes as early as late July in the Clackamas and Molalla rivers (Dimick and Merryfield 1945)) and continues through mid-October, with peak spawning in September. Dimick and Merryfield (1945), and Mattson (1963) observed that spawning generally coincided with a slight drop in water temperature following the first few cool nights. Today, Willamette River spring Chinook continue to spawn from late August through October, with peak spawning in September (Schroeder et al. 2003, Olsen et. al. 1992).

Most, if not all fall Chinook native to the Willamette Basin populated reaches below Willamette Falls, most notably the lower Clackamas River, Johnson Creek, Abernathy Creek and Scappoose Creek (Hutchinson and Aney 1964, Willis et al. 1960, Myers 2003). Today, a late-run population of Chinook salmon continues to spawn and rear in the lower Clackamas River; however, it is unknown whether these fish are of fall Chinook origin or are the later part of the spring-run. Adults enter freshwater at an advanced stage of maturity and spawn shortly after reaching their spawning grounds (from mid-September through early October). Both Stone (1878) and Barin (1886) observed Chinook salmon returning to the lower Clackamas River (just upstream of

Clear Creek) beginning in early September, with "ripe" spawning salmon observed just two weeks later in mid-September. Due to managed flows in the Willamette, and fish passage improvements at Willamette Falls (beginning in the 1880's) fall Chinook ascend Willamette Falls and spawn and rear in middle reaches of the Willamette subbasin; the McKenzie River is believed to be the only basin above the Falls to sustain significant natural production (Myers 2003).

Both spring and fall run Chinook historically and presently spawn in areas below Willamette Falls, most prominently the Clackamas River, Johnson Creek (and Crystal Springs Creek), Milton Creek, and Scappoose Creek (Hutchinson and Aney 1964, Willis et al. 1960). Today, there has been little documentation of the extended presence of adult Chinook in Johnson Creek and Crystal Springs.

Coho (*Onchorynchus kisutch*)

Historically, the lower Willamette River basin provided the third most important spawning grounds for coho salmon throughout the entire Columbia River basin (Fulton 1970). Coho are believed to be native only to subbasins below Willamette Falls, notably the Clackamas River, Johnson Creek (Fulton 1970), Tyron Creek, and tributaries of Multnomah Channel (Willis 1960). This population, now classified as the Lower Columbia River coho population (or Evolutionarily Significant Unit) is listed "endangered" under the State ESA (July 1999) and were recently listed "threatened" under the federal ESA (June 2005). Critical habitat has not yet been identified by NOAA Fisheries, however, based on historic and present fish use, the lower Willamette River (and its tributaries) up to Willamette Falls includes critical spawning and rearing habitat for this ESU.

Life history of this population is based upon native populations in the Lower Willamette River, most notably the early-run Clackamas River population. Native lower Willamette basin coho return as three-year age adults and two-year age jacks. They are an early run population, reaching Willamette Falls from late August through early November, with peak migrations occuring from middle to late September, following periods of considerable rainfall. Peak spawning generally occurs soon afterwards from September through December. Coho commonly use tributaries to lower river reaches, and spawn in small, low-gradient areas; however, they will spawn in mainstem reaches. Generally, they prefer fast-flowing waters with small to large gravel substrates (1.3 to 10.2 cm). After fertilization, eggs incubate for 80-150 days, depending on stream temperatures. Fry emerge from mid-January through April, yielding a four-month emergence period. During this period they seek shallow water areas, before dispersing downstream into deeper habitats. While a small proportion of fry emigrate during the first year, most fingerling smolts emigrate during the second spring, beginning in March and extending through mid-July. Those that remain in their natal streams will migrate upstream or downstream, seeking slack water habitats often found in side channels, backwater pools, and beaver ponds. These habitats are especially important during overwintering months because they harbor insects and provide a continual source of food for coho. Yearling juvenile coho emigrate seaward in early spring, with peak migrations in April and May. Generally, coho will rear for two additional years in the ocean and return to their natal streams as three- and four-year age adults in the fall.

Steelhead (*Onchorynchus mykiss*)

Anadromous and resident steelhead (or rainbow trout) inhabit eastside and westside tributaries of the Willamette River Basin (Dimick and Merryfield 1945). Populations below Willamette Falls are part of the larger Lower Columbia River Evolutionarily Significant Unit (ESU), listed as "threatened" under the federal Endangered Species Act in March 1998 and reaffirmed in January 2006. Critical spawning and rearing habitat was described and adopted by NOAA Fisheries in January 2006, and includes all streams and tributaries in the lower Willamette River, below Willamette Falls. Tualatin River steelhead are part of the larger Upper Willamette River ESU, which were listed in March 1998 and reaffirmed in January 2006. Critical habitat designations for these populations were adopted in January 2006; and include all of the Willamette River in Oregon, and its tributaries upstream from Willamette Falls to the Calapooia River.

The life history of lower Willamette River populations (most prominently the Clackamas River) is generally a late returning population, taking advantage of high river flows (and cool stream temperatures) to move upstream and navigate natural falls and high gradient stream reaches. The lower Willamette populations return to spawn during their fifth and sixth year. Native, late-run winter steelhead enter the Willamette River from October through May (Dimmick and Merryfield 1945). Spawning begins as early as March; however, peak spawning is believed to be greatest in April in westside tributaries and May in eastside tributaries. Steelhead spawn in cool, clear, and well-oxygenated streams with small to large gravel (1.3 to 11.4 cm) and suitable flow (0.76 meters/second) (USFWS 1983). These conditions are found in riffle-type habitats and are typical of habitat found in the upper tributary reaches. Most steelhead die after spawning, however, some will re-enter the ocean, returning to their natal stream for a second time to spawn again. Adults exhibiting this life history characteristic are called "kelts".

Eggs hatch and fry emerge in winter or early spring, depending on habitat, water temperature, and spawning season. After emergence, fry continue to rear in riffle-type habitats through the summer, then move into pools in the winter. Steelhead generally become inactive in winter months, often burrowing into stream-bottom substrates and other available instream cover. Steelhead, like Chinook, rely on an abundance of instream structure for cover during overwintering months.

Juvenile steelhead generally spend two years in freshwater before smolting, with peak juvenile emigration beginning early April and extending through early June, and larger steelhead emigrating earlier than smaller ones (ODFW 2000). Smoltification is initiated by a combination of environmental factors including photoperiod, water temperature, and water chemistry. Larger steelhead generally emigrate sooner than their smaller cohorts (ODFW 2000). Marine survival is correlated with smolt size, with the critical minimum size ranging from 14 to 16 cm upon saltwater entry. Steelhead rear in the ocean for one to four years before returning to their natal streams.

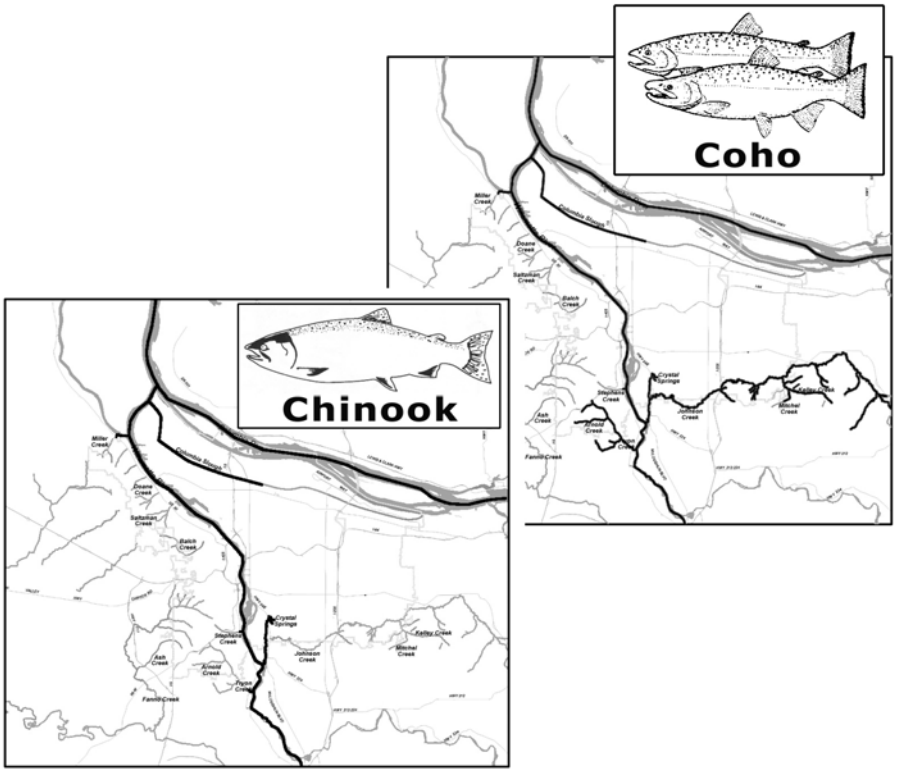

FIGURE E-2
Distribution of Chinook and Coho Salmon In Portland's Waterways

Cutthroat (*Onchorynchus clarki)*

Coastal cutthroat had the greatest overall distribution of any of the salmonids in the Willamette River Basin, and were known to populate most streams in the basin (Hutchinson and Aney 1964). Dimick and Merryfield (1945) reported "few tributaries of the Willamette system is without cutthroat trout unless blocked by natural barriers. Two life-history phases of cutthroat trout resided in Portland area streams: migratory and non-migratory. Non-migratory, or resident, cutthroat historically did not migrate far from upper tributary reaches (Hutchison and Aney 1964), remaining in fresh water for their entire lifespan. Migratory, or sea-run, cutthroat were believed to drop down into the mainstem Willamette River in the spring, rear throughout the summer, then migrate to the ocean in the fall or early winter. Notably, they did not use the mainstem reaches for spawning; rather, they used them for spring, summer, fall, and early winter rearing. Sea-run cutthroat were noted to reside predominantly near tributary confluence regions of mainstem Willamette River. The U.S. Fish and Wildlife Service previously considered Southwest Washington/Columbia River coastal cutthroat trout a "candidate" species for federal ESA listing. However, in June 2002, that agency determined that the population did not warrant protection under the ESA, based on trends in population abundance and recently enacted fish and habitat protections (that included protections by the City of Portland).

In 1945, Dimick and Merryfield noted that no morphological differences between resident and sea-run cutthroat, except for differences in the size of adults. One distinct difference they did note was related to spawn timing; sea-run cutthroat spawned in January, February, and March (much like native winter steelhead), while resident cutthroat spawned in May, June, and July. Notably, in Oregon and Washington, sea-run cutthroat return to their natal stream anytime from mid-summer through spring of the following year, with peak movement occurring from September thru October. Generally, they migrate to upper mainstem and tributary stream reaches (above favorable coho and steelhead spawning habitat), but will spawn and rear along-side other resident fish (notably, resident cutthroat and rainbow trout). Selection of these upper reaches spatially segregates them from other co-occurring salmonids and avoids competition for rearing and spawning areas. Cutthroat spawn in small- to moderate-size gravel, often in pool tail-outs. They are repeat spawners; if they survive post-spawning, they overwinter in fresh water and emigrate downstream the following spring. Adult migrations generally precede emigration of juvenile cutthroat heading seaward. Note, some female cutthroat do not spawn in the first winter after returning to freshwater (Johnston 1982). Rather, they overwinter in freshwater, then return to the ocean the following spring.

Eggs incubate for four to six weeks in the gravel. Upon emergence, fry seek shallow stream margins, with low-velocity flows. During early life history rearing cutthroat are opportunistic feeders, feeding predominately on aquatic invertebrates suspended in the water column. If other salmonids are present, fry can be easily displaced; their distribution and habitat use is therefore highly dependent on interspecific competition with other native fishes. Notably, juvenile (and adult) cutthroat generally prefer deep pools and low-velocity instream habitats, but will move either upstream and downstream to seek food, avoid competition and find better rearing habitats. Cutthroat smolt from age one to four (and sometimes later), but generally at age three or four, when they reach a size of 200 to 250 mm (fork length). Downstream migrations generally occur from March to June, peaking in mid-May. A unique characteristic that cutthroat exhibit (different from other salmonids) is that they form schools before salt-water entry and remain schooled throughout their saltwater migrations and rearing. In the ocean, cutthroat remain close to the Pacific shoreline, rearing in shallow waters. Although salt-water residence time varies among populations, cutthroat tend to re-enter freshwater in the same year they migrated to sea; hence return to their natal stream during the subsequent fall season.

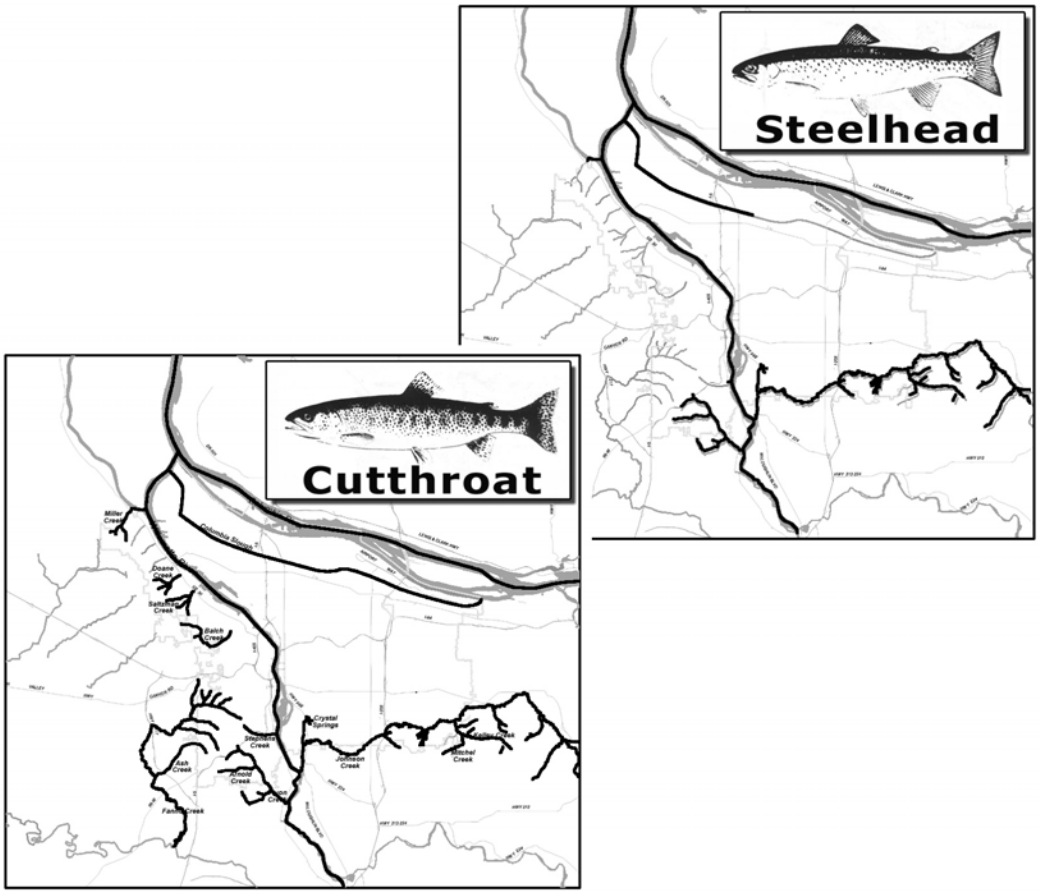

FIGURE E-3
Distribution of Steelhead and Cutthroat Trout in Portland's Waterways

Wildlife in Portland's Watersheds

The Portland metro area is fortunate to have retained some important natural areas such as Forest Park, the East Buttes, Cooper Mountain, Smith and Bybee wetlands, Big Four Corners, and other habitat that is essential for maintaining a diversity of wildlife species within the urban area. While some wildlife species that once inhabited our region are no longer found, remaining natural areas still provide habitat for many wildlife species, as well as recreational opportunities for humans (Houck and Cody 2000).

Metro's Regional Urban Growth Goals and Objectives (RUGGOs), adopted in 1995 state that "a region-wide system of linked significant wildlife habitats should be developed. This system should be preserved, restored where appropriate, and managed to maintain the region's biodiversity." Also in 1995, citizens of the Portland metro area passed a $135.6 million bond measure to acquire natural areas within the Portland metropolitan region. Metro has since acquired more than 8,000 acres of key habitat. The Metro Council will consider putting a Regional Greenspaces Bond Measure before voters in 2006. If passed, this measure would provide funds for additional land purchases as well as fish and wildlife habitat-related projects.

Amphibians

There are sixteen extant native amphibian species in the Portland metro area, including twelve salamanders and five frogs (see Metro's species list in Appendix 1 of Metro's *Technical Report for Goal 5*, revised draft dated January 2002; see http://www.metro.dst.or.us/metro/habitat/ habitat_fish_docs.html). An additional species, the bullfrog, is introduced and places considerable pressure on native species. Amphibians and birds are the two groups in the area most dependent on aquatic and riparian habitats. In the Portland area, 69 percent of native amphibian species (salamanders, toads and frogs) rely exclusively on stream- or wetland-related riparian habitat for foraging, cover, reproduction sites and habitat for aquatic larvae. Another 25 percent use these habitats during their life cycle. Six Portland-area amphibian species are state-listed species at risk; four species are considered at risk at the federal level (see Metro's species list).

Because amphibians require both aquatic and terrestrial habitats to complete their life cycle, changes to either ecosystem may interfere with amphibians' success (Schueler 1995). Small non-fish-bearing streams and beaver ponds may be important because they are free from competition and predation by fish (Gomez 1998, Metts and others 2001). As with salmonids, amphibians have specific habitat requirements and are sensitive to environmental change. Clean, relatively sediment-free water, rocky stream beds and woody debris are important to amphibians in western Oregon (Bury and others 1991, Welsh and Lind 1991, Butts and McComb 2000).

Reptiles

Thirteen native reptile species inhabit the Portland area, including two turtle, four lizard and seven snake species (see Metro's species list). This is the least riparian-associated group; even so, 23 percent of native reptile species depend on water-related habitats and another 46 percent use water-related habitats during their lives. Although most lizards and snakes are associated with upland habitats, many species use riparian areas extensively for foraging because of the high density of prey species and vegetation. Both of the native turtle species — the Northwestern pond turtle and the Western painted turtle — are riparian/wetland obligates and rely on large wood in streams, wetlands and lakes for basking (Kauffman and others 2001). These two turtles are state and/or federal species at risk. Several nonnative turtle species have established breeding populations in Portland, and they compete with native turtle species.

Birds

Birds represent the majority of vertebrate diversity in this region, and 209 native bird species occur in the Portland area (see Metro's species list). An additional four nonnative species have established breeding populations in the area. In the Portland area, about half (49 percent) of native bird species depend on riparian habitats for their daily needs, and 94 percent of all native bird species use riparian habitats at various times during their lives. Twenty-two bird species are state or federal species at risk (see Metro's species list). Nineteen of these are riparian obligates or regularly use water-based habitats. An additional riparian obligate, the yellow-billed cuckoo, is extirpated in the Portland area.

Bird abundance, species richness and diversity are typically higher in riparian habitats compared to other habitat types (Stauffer and Best 1980, LaRoe and others 1995, Kauffman and others 2001). This reflects greater plant volume and structural diversity (birds are highly threedimensional in their habitat use) and food, water and habitat resources associated with riparian vegetation (LaRoe and others 1995).

Mammals

Mammals are another diverse group of species in the Portland area, with 54 native species (see Metro's species list). This is the terrestrial group with the highest number of nonnative species (eight species, or 15 percent of total species; most are rodents). Of native species, 28 percent are closely associated with water-based habitats, with another 64 percent using these habitats at various points during their lives. Six out of nine bat species are state or federal species at risk. Three native rodent species are similarly listed.

Riparian resources are important to mammals for many of the same reasons they are important to amphibians and birds (i.e., diverse habitat structure, abundant coarse woody debris, good connectivity, access to water and a wealth of food resources) (Butts and McComb 2000, Kauffman and others 2001). In Pacific Northwest forests, multispecies canopies, coarse woody debris and well-developed understories (dominated by herbs, deciduous shrubs and shade-tolerant seedlings) are important to small mammal biodiversity across a broad spatial scale (Carey and Johnson 1995). Other Pacific Northwest studies have shown increased small mammal abundance and/or diversity with increasing coarse woody debris (McComb and others 1993, Butts and McComb 2000, Wilson and Carey 2000). Riparian forests contain high amounts of coarse woody debris, and this may be why some studies document higher small mammal abundance in riparian habitats than in uplands (Doyle 1990, Menzel and others 1999, Bellows and Mitchell 2000).

Mammals can profoundly influence habitat conditions for other animals, including fish. Beaver, a keystone species in riparian areas, play a critical role in the creation and maintenance of wetlands and stream complexity and may have broad effects on physical, chemical and biological characteristics within a watershed (Cirmo and Driscoll 1993, Snodgrass 1997, Schlosser and Kallemeyn 2000). Historically, beavers were nearly extirpated from the Willamette Valley as a result of trapping, but populations have rebounded (Oregon Department of Fish and Wildlife 2001). Large herbivores such as deer browse on herbs and shrubs, which can promote vigorous growth (Kauffman and others 2001). Medium-sized carnivores keep rodent and small predator populations in check, with important implications for bird nest success. Bats help regulate insect populations and may contribute to nutrient cycling, particularly in riparian areas (LaRoe and others 1995).

Priority Wildlife Habitat Types and Wildlife Species

In 2005, the Oregon Natural Heritage Information Center developed preliminary lists of priority wildlife habitats and species that should be considered for future conservation actions in Portland[4]. Those lists have been augmented by City staff, and will be refined over time. At this

[4] There are several classification systems that are useful in understanding the biological communities and habitats in the Portland area. In addition to the "Habitat Types" developed by Johnson and O'Neil (2001), presented earlier in this appendix, there are "Ecological Systems" and "Wildlife Habitat" classifications. Ecological systems and wildlife habitat classifications are similar. The distinction is that ecological systems are biological communities that occur in similar physical environments and are influenced by similar dynamic ecological processes (such as fire or flooding). They are vegetation-based classifications. Wildlife habitat classifications are similar, but include tree size classes and structural components that may be important to wildlife species. Because the ecological systems and wildlife habitats classifications are similar, only the priority habitats and species are presented in Tables E-1 and E-2. The Oregon Natural Heritage Information Center developed a "cross-walk" matrix showing the relationships between the various classification systems.

time, invertebrates and plants are not included. In the future, City staff also will determine wildlife species-habitat associations, associations with aquatic species and habitats, and develop objectives, measures and actions to achieve the Physical Habitat and Biological Communities goals.

Priority Wildlife Habitat Types in Portland

The following wildlife habitat types are considered important for possible future conservation and/or restoration for the reasons listed.

TABLE E-1
Priority Wildlife Habitats in Portland and Reasons for High Importance

PRIORITY WILDLIFE HABITATS	REASONS FOR HIGH IMPORTANCE
Marsh	Diminished habitat extent; importance for water quality and fish protection.
Large Mixed Conifer-Deciduous	Diminished habitat extent. There are opportunities in the City of Portland for development of legacy old-growth stands and control of exotics.
Oak	Diminished habitat and rare or at-risk species associated with oak woodlands and savannah.
Westside Grasslands	Important statewide for diminished habitat extent and rare species associated with them. Exotic species are of concern.
Westside Riparian	Important for water quality and fish protection. Most occurrences are fragmented and of low quality because of buffer widths, lack of tree overstory and abundant exotic species. There are many restoration opportunities in the City of Portland to improve buffer widths and riparian vegetation, remove barriers, and daylight culverted stream reaches.
Medium Mixed Conifer-Deciduous	Diminished habitat extent. There are opportunities in the City of Portland for development of legacy old-growth stands and control of exotics.
Medium West Side Douglas-fir Mixed Conifer	Diminished habitat extent. There are opportunities in the City of Portland for develop of legacy old-growth stands and control of exotics.

Priority Wildlife Species in Portland

The amphibians, reptiles, birds and mammals potentially having high priority for conservation with the City of Portland, along with reasons for their importance are listed in Table E-2. Species considered priorities are those that:

- are known to be showing population declines, either regionally or more broadly, and for which conservation or restoration efforts by the City of Portland may be particularly beneficial;
- have been listed as priorities by the Oregon Watershed Enhancement Board in its process of identifying land acquisition priorities;

- have been designated with some federal or state status (e.g., federally-listed under the Endangered Species Act, classified by the Oregon Fish and Wildlife Commission as a Sensitive Species[5]) and/or
- have been identified as "focal species" by Partners In Flight (PIF)[6] in the "Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington" or "Conservation Strategy for Landbirds in Coniferous Forests of Western Oregon and Washington".

TABLE E-2
Priority Wildlife Species in Portland and Reasons for High Importance

PRIORITY SPECIES[7]	REASONS FOR HIGH IMPORTANCE
Amphibians	
Northern red-legged frog	USFWS Species of Concern; ODFW Sensitive Species (Vulnerable); OWEB priority; general pattern of extirpation continues where introduced warm water fishes and bullfrogs have invaded (recruitment is very low in these areas)*
Reptiles	
Western painted turtle	ODFW Sensitive Species (Critical); OWEB priority; continuing habitat loss and high predation of nests by raccoons and of juveniles by non-native warm water fishes and bullfrogs*
Northwestern pond turtle	USFWS Species of Concern; ODFW Sensitive Species (Critical); OWEB priority; continues to decline from lack of recruitment, urbanization, predation, and agricultural practices*
Birds	
American bittern	OWEB priority; lack of high-quality, large freshwater wetlands
Great blue heron	OWEB priority; declining regional populations; sensitive to expanding disturbances
Hooded merganser	OWEB priority; nest in tree cavities, not always adjacent to a body of water
Bald eagle	USFWS Threatened; ODFW Threatened
Northern harrier	PIF focal species; loss/fragmentation of large wetland/upland prairie complexes

[5] Sensitive Species are those naturally-reproducing native animals which may become threatened or endangered throughout all or any significant portion of their range in Oregon (OAR 635-100-140). There are four sub-categories of Sensitive Species—Critical, Vulnerable, Peripheral or Naturally Rare, and Undetermined Status.

[6] Partners In Flight is an international effort aimed at ensuring healthy populations of native landbirds. The Bird Conservation Plan was developed by American Bird Conservancy, in cooperation with numerous individuals, agencies and organizations within the Oregon-Washington chapter of Partners In Flight.

[7] Species generally are listed in phylogenetic order, not necessarily in order or importance.

* Also identified as a "Strategy Species" in the Oregon Department of Fish and Wildlife's Draft Comprehensive Wildlife Conservation Strategy for Oregon (2005) for the Willamette Valley Ecoregion. "Strategy Species" are those closely associated with "Strategy Habitats" or are declining for a variety of reasons. It should be noted that small parts of Portland are within two other ecoregions—the Coast Range and West Cascades. There may be additional species that could be considered "Strategy Species".

American kestrel	OWEB priority; PIF focal species; highly significant declining trend; loss of old oak savannah trees with cavities for nesting
(American) Peregrine falcon	ODFW Endangered
Dunlin	OWEB priority; wetlands and flooded fields important for non-breeding season foraging
Band-tailed pigeon	USFWS Species of Concern; OWEB priority; highly significant declining trend; needs closed canopy coniferous forests for nesting and open canopy coniferous forests for foraging
Short-eared owl	OWEB priority; loss/fragmentation of large wetland/upland prairie complexes*
Vaux's swift	PIF focal species; loss of late-stage seral forests with snags for nest and roost sites; significantly declining population trends at regional and western Oregon and Washington levels
Downy woodpecker	PIF focal species; needs deciduous riparian snags; competition with European starlings for nest cavities
Pileated woodpecker	ODFW Sensitive Species (Vulnerable); PIF focal species; needs mature, large trees and snags for nesting, roosting and foraging; needs dense canopy to provide cover from predators
Olive-sided flycatcher	USFWS Species of Concern; ODFW Sensitive Species (Vulnerable); OWEB priority; PIF focal species; significantly declining population trends at regional and western Oregon and Washington levels
Western wood-pewee	PIF focal species; highly significant declining trend; loss/degradation of riparian gallery forest and oak woodland openings and edges
Willow flycatcher	ODFW Sensitive Species (Vulnerable); OWEB priority; PIF focal species; highly significant declining trends at regional and western Oregon levels; needs dense riparian shrub habitat*
Pacific-slope flycatcher	OWEB priority; PIF focal species; needs mature/young deciduous canopy trees; significantly declining population trends at regional, western Oregon and Washington levels
Red-eyed vireo	PIF focal species; fragmented riparian gallery forest (especially cottonwood) along the Columbia River and tributaries
Streaked horned lark	USFWS Candidate Species; ODFW Sensitive Species (Critical); OWEB priority; PIF focal species; small and local populations lack protection; needs short grass with areas of bare ground for nesting; significantly impacted by land management (e.g., mowing, tilling)*
Purple martin	USFWS Species of Concern; ODFW Sensitive Species (Critical); OWEB priority; PIF focal species; loss of large snags with cavities in open forest and adjacent large bodies of water*
White-breasted nuthatch	OWEB priority; PIF focal species; highly significant declining trends; loss/degradation of large patches of oak woodlands and savannah, especially with old trees*
Swainson's thrush	PIF focal species; needs dense understory riparian shrub habitat
Yellow warbler	OWEB priority; PIF focal species; significant declining population trend; loss/fragmentation of structurally diverse riparian woodlands and thickets dominated by willow and cottonwood

Yellow-breasted chat	ODFW Sensitive Species (Critical in the Willamette Valley Ecoregion); long-term declining trend; needs riparian shrub habitat*
Chipping sparrow	OWEB priority; PIF focal species; highly significant declining trend; loss/degradation of oak woodlands with an open, herbaceous understory*
Oregon vesper sparrow	USFWS Species of Concern (*affinis* subspecies); ODFW Sensitive Species (Critical); OWEB priority; PIF focal species; vulnerable small and local populations lack protection; needs grassland with scattered shrubs and/or bunchgrass; significantly impacted by land management such as mowing and grazing*
Tri-colored blackbird	USFWS Species of Concern; ODFW Sensitive Species (Peripheral or Naturally Rare); loss of wetland habitats for breeding
Western meadowlark	ODFW Sensitive Species (Critical in the Willamette Valley ecoregion); OWEB priority; PIF focal species; highly significant declining trends; requires large patches of grassland habitat; loss/degradation of grassland/prairie and oak savannah habitat; significantly impacted by land management (e.g., mowing, grazing)*
Bullock's oriole	OWEB priority; PIF focal species; highly significant declining trends at regional and western Oregon levels; fragmented riparian gallery forest (especially cottonwood) along the Columbia River and tributaries
Mammals	
California myotis (bat)	ODFW Sensitive Species (Vulnerable)*
Yuma myotis (bat)	USFWS Species of Concern
Long-legged myotis (bat)	USFWS Species of Concern; ODFW Sensitive Species (Undetermined)
Fringed myotis (bat)	USFWS Species of Concern; ODFW Sensitive Species (Vulnerable)
Long-eared myotis (bat)	USFWS Species of Concern; ODFW Sensitive Species (Undetermined)
Silver-haired bat	USFWS Species of Concern; ODFW Sensitive Species (Undetermined)
Pacific western big-eared bat	USFWS Species of Concern; ODFW Sensitive Species (Critical)*
Western gray squirrel	ODFW Sensitive Species (Undetermined)*

APPENDIX F

Setting Viable Salmonid Population Goals

APPENDIX F

Setting Viable Salmonid Population Goals[1]

The National Marine Fisheries Service in the National Oceanic and Atmospheric Administration (NOAA Fisheries) has a Technical Recovery Team for the Lower Columbia River evolutionarily significant units (ESUs) of steelhead, Chinook and coho salmon. This team is responsible for setting viable salmonid population goals for the ESU. The City of Portland is working with the Technical Recovery Team to ensure that the City's watershed management efforts are consistent with salmonid recovery planning throughout the region.

Efforts to restore salmon (*Oncorhynchus* Sp.) populations in the Pacific Northwest have traditionally focused on the limiting factors—the bottlenecks—that restrict abundance. The assumption behind this approach was that abundance is the principal determinant of population performance. NOAA Fisheries now believes that recovery of viable salmonid populations must address not only the population parameter of abundance but also other important determinants of population health, such as productivity, diversity and spatial structure (McElhany and others 2000). When making listing decisions regarding Pacific salmonids, NOAA Fisheries' policy is to list ESUs as "distinct population segments" under the Endangered Species Act (McElhany and others 2000). However, there is wide recognition of the need to undertake conservation actions for all population sizes.

Population Performance Measures

NOAA Fisheries defines population performance measures in terms of four key parameters: abundance, productivity, spatial structure and diversity. These parameters are useful population viability guidelines for several reasons: (1) they are reasonable predictors of extinction risk (viability), (2) they reflect general processes (habitat quality, interactions with other species, etc.) that are important to all populations of all species, and (3) they are measurable (McElhany and others 2000). Finally, the parameters can be linked to salmonid life history and habitat relationships. Diversity can be discussed in the context of salmonid life histories, spatial structure can be described as the relationship between life histories and habitat and productivity depends on a network of complex and interconnected habitats that allows adaptations to occur. Together, they determine potential population productivity.

Guidelines for each of the four key parameters—abundance, productivity, spatial structure and diversity—have been defined by NOAA Fisheries (McElhany and others 2000). The parameters and guidelines for their application are described below.

Abundance

All else being equal, small populations are at greater risk than large populations because processes that affect population dynamics operate differently in small populations than they do in large populations. The following guidelines assess population viability based on

[1] This appendix is intended to present an overview of this subject. For more detailed information, readers should consult additional sources.

abundance. Two sets of guidelines are described below: viable size guidelines and critical size guidelines.

With respect to abundance, a population must meet all of the viable population guidelines to be considered viable. If a population meets even one critical guideline, that population is considered to be at a critically low level. NOAA Fisheries also requires that population status evaluations take uncertainty about abundance into account.

Because extinction risk depends largely on specific life-history strategies and the local environment, setting fish abundance levels will require the application of species- or population-specific information. No numerical criteria have been provided by NOAA Fisheries at this time (McElhany and others 2000).

Viable Population Size Guidelines. To be considered viable with respect to abundance, a population should:

- Be large enough to survive environmental variation of magnitudes observed in the past.
- Have sufficient abundance for any compensatory density-dependent processes that affect the population to provide resilience to environmental and anthropogenic perturbation. (An example of a compensatory process is where resources are not sufficient to support a population at a certain level of abundance. As the population decreases in abundance, the remaining members of the population are able to locate the necessary resources to meet critical needs).
- Be sufficiently large to maintain its genetic diversity over the long term.
- Be sufficiently abundant to provide important ecological functions in all the environments it occupies.

Critical Population Size Guidelines. A population would be critically low in abundance if:

- Depensatory processes were likely to reduce it below replacement. (Depensatory processes are processes—such as the ability to find a mate—that would result in decreased productivity with decreasing density. Conversely, compensatory processes are processes—such as competition for food or habitat—that result in an increase in productivity with decreasing density.)
- The population could not avoid the short-term effects of inbreeding depression or loss of rare alleles (genetic material).
- The variation in productivity as a result of demographic stochasticity became a substantial source of risk.

Productivity

Productivity over the entire life cycle is partially accounted for in the process of assessing abundance because abundance integrates productivity over time. The guidelines for productivity are closely linked with those for abundance.

Trends in abundance reflect changes in factors that drive a population's dynamics and thus determine its abundance. NOAA Fisheries is most concerned with trends in abundance that reflect systematic changes in a population's dynamics. Negative trends in abundance are an indication of extinction risk for populations in decline—no matter what the cause. The guidelines presented below are often conditioned on a population's status in terms of abundance.

Productivity Guidelines. A viable salmonid population should:

- Have a natural productivity that is sufficient to maintain its abundance above the viable level.
- Exhibit sufficient productivity from naturally produced spawners to maintain population abundance at or above viability thresholds in the absence of hatchery subsidy. (This applies to salmonid populations that include naturally spawning hatchery fish.)
- Exhibit sufficient productivity during freshwater life-history stages to maintain its abundance at or above viable thresholds—even during poor ocean conditions.
- Not exhibit sustained declines in abundance that span multiple generations and affect multiple broodyear-cycles.
- Not exhibit trends in traits that portend productivity declines.

Spatial Structure

When evaluating population viability, it is important to take within-population spatial structure needs into account for two main reasons:

- Short-term observations of abundance and productivity may not be sensitive enough to detect the time lag between changes in spatial structure and species-level effects that may have an effect on the overall extinction risk at the 100-year time scale.
- Population spatial structure affects evolutionary processes and may therefore alter a population's ability to respond to environmental change.

A population's spatial structure is made up of both the geographic distribution of individuals within the population and the processes that generate that distribution. A population's spatial structure depends fundamentally on habitat quality, spatial configuration and dynamics, as well as the dispersal characteristics of individuals in the population.

Spatial scales that define habitat patches and subpopulation boundaries are not strictly defined here because such determinations are likely to be species- and population-specific. NOAA Fisheries has emphasized that salmonid spatial structure is not well understood, and there is currently no scientific consensus on what a "typical" spatial structure is (McElhany and others 2000). The guidelines below focus on key processes that are likely to be important in maintaining a viable spatial structure, regardless of population type.

Spatial Structure Guidelines

- Habitat patches should not be destroyed faster than they are created.

- Natural rates of straying among subpopulations should not be substantially increased or decreased by human actions.
- Some habitat patches that appear to be suitable or marginally suitable but currently contain no fish should be maintained.
- Source subpopulations should be maintained.

Diversity

In a spatially and temporally varying environment, diversity is important for species and population viability for three general reasons:

- Diversity allows a species to use a wider array of environments than it could without it.
- Diversity protects a species against short-term spatial and temporal changes in the environment. Fish with different characteristics have different likelihoods of persisting, depending on local environmental conditions. The more diverse a population is, the more likely it is that some individuals will survive and reproduce in the face of environmental variation (Primary Ecological Principle 7).
- Genetic diversity provides the raw material for surviving long-term environmental changes. Salmonids regularly face cyclic or directional changes in their freshwater, estuarine and ocean environments as a result of natural and human changes. Genetic diversity allows the species to adapt to these changes.

Diversity Guidelines

- Human-caused factors such as habitat changes, harvest pressures, artificial propagation and the introduction of exotic species should not substantially alter traits such as run timing, age structure, size, fecundity, morphology, behavior and molecular genetic characteristics.
- Natural processes of dispersal should be maintained. Human-caused factors should not substantially alter the rate of gene flow among populations.
- Natural processes that cause ecological variation should be maintained.
- Population status evaluations should take into account uncertainty about requisite levels of diversity.

As a result of these considerations, the City of Portland has established general fish and habitat goals for the Johnson and Tryon Creek watersheds that include the following population performance measures:

1. Habitat conditions in the Johnson Creek watershed allow fish populations to achieve the necessary abundance, productivity, spatial structure and diversity to promote the survival and recovery of listed species.
2. Habitat conditions in the Tryon Creek watershed allow fish populations to achieve the necessary abundance, productivity, spatial structure and diversity to promote the survival and recovery of listed species.

The City of Portland's Role

While the City of Portland does not have management authority over salmonid populations, it does maintain authority over infrastructure and land use decisions that affect habitat and ecological processes through planning, permitting and enforcement. NOAA Fisheries has indicated that while habitat characteristics are not part of the viability criteria, their effects are ultimately reflected in the four population parameters (McElhany and others 2000). For example, a population's spatial structure is to a large degree dictated by habitat structure. The spatial structure guidelines reflect this. As a result, the City of Portland believes that the viable salmonid population (VSP) population criteria can be met largely through the restoration of habitat functions.

NOAA Fisheries has indicated that an approach that delineates habitat standards that are related to the health of an entire salmon population must occur at a watershed or subwatershed scale—a larger spatial scale than is usually examined in habitat analyses (McElhany and others 2000). Most current habitat standards establish criteria at fine spatial scales—at the reach level or smaller. (An example is the Matrix of Pathways and Indicators in NOAA Fisheries' Properly Functioning Conditions [PFC] document [National Marine Fisheries Service 1996]).

If habitat standards can be developed at larger spatial scales, a better relationship between habitat and population levels can be established. Identification of the characteristics common to those subwatersheds that support high productivity, diversity, abundance and spatial structure will enable a set of watershed-level habitat goals to be developed.

The City of Portland recognizes that NOAA Fisheries and the Willamette Technical Recovery Team (TRT) must play a role in the development of these goals. The City has embarked on an ambitious schedule of data collection, planning and analysis that could inform these discussions. A combination of fish and habitat inventories are either under way or proposed; they include (1) a four-year Willamette River fish use study to determine how juvenile salmonids are using the variety of habitat types that exist in the lower river, (2) aquatic habitat inventories in all of Portland's watersheds, and (3) studies of salmonid presence and seasonal habitat use in all of Portland's tributary streams.

In addition, the City of Portland developed an analytical tool for use in the watershed management process presented in the *Framework for Integrated Management of Watershed Health*. The City of Portland adapted an Ecosystem Diagnosis and Treatment (EDT) model (Lichatowich and others 1995) to assist in the analysis of alternative recovery options. The City will work closely with NOAA Fisheries, the TRT and other interested parties to ensure that this approach is consistent with salmonid recovery planning goals throughout the region.

APPENDIX G

Selecting Indicators of Watershed Health

APPENDIX G

Selecting Indicators of Watershed Health

For the watershed management process described in the *Framework* to be successful, the City of Portland must be able to measure its progress in meeting the objectives established for each of the City's watersheds. To do so requires having a set of carefully selected indicators of watershed health that can be monitored over time. This appendix presents a rationale for selecting indicators of watershed health and describes various environmental attributes and influences that, together, constitute the suggested indicators for use in the City's watersheds. However, the final list of indicators to be used will be tailored according to the site-specific conditions in each watershed and the objectives established for each watershed. Specific values to be used as targets or benchmarks for these indicators are not suggested. Rather, such values will be developed during the watershed process and tailored to the conditions in each watershed and the watershed-specific objectives, based on the characterization work.

What Are Indicators?

Indicators are readily measurable attributes that reflect the conditions and dynamics of broad, complex attributes of ecosystem health that may be difficult to measure directly. Indicators represent the physical, biological and chemical attributes of an ecosystem and can provide a means of evaluating particular components of a complex system.

Indicators are essential in any scientific effort to restore watershed health because they serve as links between goals and actions. A well-designed watershed management plan typically has a set of goals, each of which—to be useful—is broken down into one or more specific, measurable objectives. Each objective, in turn, is defined further by identifying readily measurable indicators and desired conditions for those indicators (desired conditions are often expressed as target values or ranges of values). Over time, conditions can be monitored and compared with the target values, so that progress in meeting the objective can be measured. Also useful in determining progress are benchmarks, which are specific values or conditions to be achieved at various points along the way, before a particular objective is actually met. Benchmarks also can be useful in periodically evaluating and refining the desired condition or target value for an indicator.

Links from Goals to Actions

Citywide and watershed-specific goals

↓

Watershed-specific objectives

↓

Watershed-specific watershed health indicators

↓

Reference conditions for selected indicators

↓

Desired conditions or target values for selected indicators

↓

Watershed-specific benchmarks for selected indicators

↓

Restoration and protection actions and monitoring of indicators

As discussed in Restoration Guideline 2, the selection of indicators for characterizing the health of watersheds is critical. The indicators must be comprehensive enough that they capture the major components and processes that constitute watershed health, yet they must be measurable at a scale and frequency that are practicable. The factors affecting any ecosystem or species are numerous and complex, and it is unlikely that every process and component of an ecosystem can be measured (Barber 1994). The concept of indicators reflects this reality; indicators are an attempt to represent a highly complex ecosystem using a set of defined, measurable attributes of ecosystem health.

Indicators are readily measurable attributes that reflect the condition and dynamics of broader, more complex attributes of ecosystem health. Indicators are an attempt to represent a highly complex ecosystem using a set of defined, measurable attributes.

For example, watershed managers might measure fecal coliforms rather than the numerous individual human pathogens with which fecal coliforms are associated. Although the presence and abundance of the other human pathogens may be the most relevant information in protecting human health, these organisms are difficult to measure, and it is believed that the abundance of fecal coliforms is proportional to the abundance of pathogens. Thus fecal coliforms serve as an indicator for broader threats to human health.

Benthic macroinvertebrates such as mayflies and caddis flies are similarly used to evaluate broader aspects of ecosystem health, for several reasons:

- They are useful as a screening tool because their populations respond relatively quickly to a whole suite of environmental attributes, including water quality, habitat and flow.
- Their presence can indicate whether attributes that are expensive or difficult to measure, such as toxic contaminants, are affecting stream health.
- They are useful in evaluating cumulative impacts on stream health that may not be detected by evaluating measured attributes individually. This can be the case even if a large set of environmental measurements is available.

Indicators often focus on structural and compositional components of the ecosystem, rather than directly on processes or functions (Mulder and others 1999). This is a matter of practicality rather than priority, as it is easier to measure the width, vegetative composition and connectivity of a riparian area, for example, than to measure the myriad complex functions that the riparian area provides, such as maintaining water quality, providing microclimates, supplying organic inputs into the food web, supplying wood and other functions related to habitat maintenance, channel dynamics and stream morphology.

Characteristics of Good Indicators

- They are directly related to objectives.
- They are readily measurable.
- They are comprehensive and accurately reflect watershed health.
- They convey an understanding of how the ecosystem functions.
- They provide insight into the cause-and-effect relationships between environmental stressors and the response of the ecosystem.

Taken together, a set of indicators should convey an understanding of how the ecosystem functions and the components most important to that functioning. As stated in *The Strategy and Design of the Effectiveness Monitoring Program for the Northwest Forest Plan* (Mulder and others 1999), indicators should provide insight into cause-and-effect relationships between environmental stressors and anticipated ecosystem responses. The indicators chosen for a particular characterization or restoration effort should be based on a conceptual model that clearly links stressors, environmental indicators and ecosystem structure and function. The effect of stressors on indicators should be clear, as should the effect of changes in indicators on the ecosystem's structure and function (National Research Council 1995).

Ideally indicators should meet a broad range of criteria (Barber 1994, Reid and Furniss in press), including but not limited to, the following:

- Be relevant to ecologically significant phenomena and closely tied to management goals and objectives
- Be sensitive to stressors
- Have high "signal-to-noise" ratios, meaning that significant changes in an indicator are due to changes in stressors rather than stochastic variability
- Be quantifiable, accurate and precise
- Be representative of the larger resources of concern
- Provide measurements that can be interpreted unambiguously
- Be cost-effective to monitor

Clearly, many indicators used in monitoring programs across the country, and particularly channel habitat indicators (Baur and Ralph 1999, Reid and Furniss in press), do not meet one or more of these criteria. Indicator development is an area requiring a great deal of focused research before all indicators will fulfill these rigorous criteria (National Research Council 1995). The suggested indicators that the City of Portland describes in this appendix attempt to reflect the state of the science on indicators. As the science develops and as the City applies selected indicators to individual watersheds, insights and information will be gained that can be used to refine the selection of indicators.

Suggested Indicators of Watershed Health

This section outlines the conceptual foundation on which the selection of indicators for Portland's watershed planning is based. The indicators discussed in this appendix are presented as a starting place from which to select specific watershed health indicators for each of the individual watersheds. These suggested indicators are consistent with the efforts of the National Marine Fisheries Service in the Oceanic and Atmospheric Administration (NOAA Fisheries), which has developed a tool—the Matrix of Pathways and Indicators (National Marine Fisheries Service 1996b)—to evaluate the effects of human actions on habitat components important to salmonids. As part of the Matrix of Pathways and Indicators, NOAA Fisheries developed the concept of "properly functioning conditions" (PFCs) to describe the habitat conditions required to support salmonids.

The document describing the Matrix of Pathways and Indicators (National Marine Fisheries Service 1996b) makes it clear that not all of the indicators in the matrix necessarily apply to watershed types or land uses that differ from the ones for which the original matrix was developed. NOAA Fisheries originally developed the Matrix of Pathways and Indicators for high-gradient, forested landscapes, primarily to evaluate the effects of actions associated with the forest products industry. Evaluating conditions in urban watersheds requires an adapted matrix. NOAA Fisheries is in the process of developing matrices of pathways and indicators for urban land uses and for different types of waterbodies. However, these adapted matrices were not available at the time of publication of the *Framework*. Through a regional workshop sponsored by the City of Portland's Endangered Species Act Program in 1999, the City of Portland has identified indicators from the original matrix that are relevant to urban watersheds. The City also has developed additional indicators that specifically address the structure of, function of, and impacts to local urban watersheds, based on what the City has learned about conditions in Portland-area watersheds. It should be noted that the indicators described in this appendix are not the final list of watershed health indicators the City will use; rather, they serve as the basis from which the actual indicators for each watershed will be selected.

The City has adapted indicators from NOAA Fisheries' Matrix of Pathways and Indicators and developed new indicators that pertain specifically to urban watersheds. The resulting list will serve as the basis from which the actual indicators for each watershed will be selected.

The set of indicators suggested by the City of Portland in this *Framework* and those that are ultimately used for measuring watershed health within specific watersheds and subwatersheds (as well as the concepts on which they are based) will be refined over time. In particular, the concepts underlying the selection of indicators will be developed further to identify in greater detail the mechanistic and functional connections among the identified components of the riverine-riparian ecosystem. Additional indicators for terrestrial species and habitats in the ecosystem will be selected in the future.

The indicators used to measure watershed health within specific watersheds and subwatersheds will be refined over time to better reflect the connections among the components of the ecosystem.

A central assumption underlying the set of attributes used in characterization, and ultimately the indicators that the City of Portland will use to evaluate watershed health, is that watershed conditions are defined by three major elements: landscape factors, specific attributes of watershed health, and human influences and activities across the watershed. These three elements are shown in Table G-1 and described in the rest of this appendix.

Landscape Factors

Landscape factors are broad-scale influences such as climate, geology, topography and soils that play a major role in determining the structure, dynamics and function of a watershed. Landscape factors set constraints on, and in many ways determine, the form and function of a watershed. They are characterized and understood through the use of watershed classification systems (Restoration Guideline 1.2) and ecoregional classification (Omernik and Bailey 1997).

TABLE G-1
Factors That Influence Watershed Conditions

Landscape Factors ➔	Watershed Health Attributes (Potential Indicators)	🡐 Human Influences
Climate	**Hydrology**	Land use
Physiography	Hydrograph alteration	Impervious surfaces
Lithology/soils	Floodplain presence and connectivity	Dam impacts
Watershed morphology	Groundwater	Water withdrawals
Hydrology		Drainage network
Vegetation		Channel alterations
	Physical Habitat	Vegetation management
	Floodplain quality and connectivity	Wetland alteration
	Riparian condition: width, composition and fragmentation	Outfall discharges
		Exotic species
	Stream connectivity	Harassment
	Channel condition and habitat structure:	Harvest
	- Habitat types	Hatchery management
	- Bank erosion	Spills and illicit discharges
	- Channel substrate (fine/coarse)	
	- Off-channel habitat (tributary and side channels)	
	- Refugia (depth, boulders, undercut banks and wood)	
	- Large wood	
	Terrestrial habitat (e.g., oak woodland)	
	Wetland habitat	
	Water Quality	
	Water temperature	
	Dissolved oxygen	
	Nutrients and chlorophyll *a*	
	Total suspended solids	
	Toxic contamination of water, sediments and biota	
	Groundwater quality	
	Other 303(d)-listed TMDL parameters	
	Other parameters (as determined by weight of evidence)	
	Biological Communities	
	Biotic integrity	
	Benthic communities	
	Salmonid population structure (abundance, productivity, spatial structure, diversity)	
	Species interactions (predation, competition, exotic species, etc.)	
	Riparian wildlife	
	Terrestrial wildlife	
	Plant communities	

Landscape factors themselves are not environmental indicators, but they are fundamental factors that strongly influence the conditions within a watershed. Therefore, understanding landscaping factors helps in interpreting current and predicted conditions of indicators. Landscape factors are described during the characterization stage of the watershed planning process to understand historical or properly functioning conditions. Later, they are used when setting watershed health objectives, targets and benchmarks. For example, landscape factors could be useful in determining an appropriate target for stream temperature that accounts for natural local conditions, or in setting targets for the amount of wood desired in a particular stream reach. Information about landscape factors is also useful when planning and implementing actions, such as when determining the type of vegetative community that should be reestablished as part of a restoration project. For example, in high-gradient streams with significant groundwater input, landscape factors might point to conifer-dominated plant communities and a relatively low value for stream temperature as appropriate objectives, whereas for a large, low-gradient river, landscape factors might suggest higher stream temperatures and cottonwood gallery forests.

Landscape factors themselves are not environmental indicators, but they strongly influence conditions in watersheds. Therefore, it is helpful to understand landscape factors when interpreting the condition of indicators.

Watershed Health Indicators

The *Framework* lays out an approach for getting from watershed health goals and objectives to actions and results. To know whether goals and objectives are being achieved requires knowing what to measure—that is, the indicators of watershed health. The *Framework* presents watershed health indicators that fall under the four categories of goals—hydrology, physical habitat, water quality and biological communities—and recognizes that healthy watersheds include healthy riparian-riverine *and* terrestrial ecosystems and biological communities. The primary ecological principles in Chapter 2, many aspects of the riverine, wetland and upland principles and the restoration guidelines apply to terrestrial species and habitats as well as to aquatic.

To achieve healthy watersheds, both aquatic and terrestrial components will need to be addressed.

The National Research Council (NRC) says that "rivers and their floodplains are so intimately linked that they should be understood, managed, and restored as integral parts of a single ecosystem" (National Research Council 1992, pp. 184-185). The NRC defines the general term "riverine-riparian ecosystem" to include both large systems—where large rivers and their floodplains form a single ecosystem—and small systems—where streams and their riparian zones form a single ecosystem.

The *Framework* evaluates the integrity of watersheds through four major categories of watershed health indicators: watershed hydrology, physical habitat, water quality and biological communities. Indicators will be established for each category and will describe the health of the ecosystem in the following ways:

- By identifying the ecological functions currently being provided in the watershed. This information, when combined with information on landscape factors and evaluations of reference areas (that is, sites whose landscape factors are similar but that are subject to fewer human disturbances), can help identify ecological functions lost as a result of human impacts.

- By revealing how the ecosystem responds to stressors, as described by the National Research Council (1995).
- By representing components of watershed processes and habitat functions that are key to supporting healthy watersheds and healthy, self-sustaining populations of salmon and other organisms.

While the watershed health indicators reflect conditions with which many protection and restoration programs are concerned, these indicators are not effective in identifying the causes of any identified degraded conditions. As discussed in Restoration Guideline 3.3, degradation of a component of the ecosystem could be attributable to any number of potential causes. For restoration actions to be effective, careful effort must be directed toward identifying and quantifying the sources of degradation so that appropriate solutions are developed. The indicators of human influences are particularly useful in this effort.

Evaluating the watershed health indicators described below can provide a tremendous amount of insight into the status of a watershed and the types of factors that threaten its integrity. To prioritize stream reaches and degraded conditions that should be addressed through restoration, the City of Portland employs technical methods and analytical tools (described in Appendix H) that make use of the measurements of the following watershed health indicators. It is important to keep in mind the linkages between the indicators described here and the ecosystem functions and processes they represent. These linkages are presented in Table G-6, after each of the watershed health indicators is described.

Hydrology Indicators

Development within urban landscapes has altered the hydrology of urban watersheds extensively. Many of the activities and actions associated with urbanization contribute directly or indirectly to substantial changes in the magnitude, frequency, timing and duration of stream and river flows. For example, the proliferation of impervious surfaces in urban watersheds dramatically increases peak flows (Leopold 1968, Hollis 1975, Booth 1991), which can cause direct mortality of salmonids, force salmonids from rearing areas and degrade physical habitat. Impervious surfaces may also reduce groundwater recharge and thereby reduce summer baseflows, which, in turn, can lead to the dewatering of smaller tributaries and, in larger tributaries, increased stream temperatures and decreased levels of dissolved oxygen.

Flows in the Willamette and Columbia rivers in the Portland area are most affected by alterations in flow from various upriver activities, such as reservoir operations. However, at the local scale, key factors acting on flow in Portland tributaries (as in other urban settings) include replacing natural vegetation with impervious surfaces, altering floodplain storage capacity and the frequency of floodplain inundation, and withdrawing water.

A1: Hydrograph Alteration. As described in detail in Riverine, Wetland and Upland Ecology Principle 3, flow alteration is a key factor affecting the suitability of habitat for salmonids and many other species in all of Portland's watercourses. Flow in tributaries is altered by a wide variety of urban activities, including the proliferation of impervious surfaces, significant diversions or manipulations in flows, channelization or operation of flood control structures. In contrast, in large rivers the primary influences on flow are various upriver effects, such as reservoir operations, rather than increases in the amount of local impervious areas (although impervious areas do have impacts on other aspects of watershed health, such as water quality). Comparing existing flow conditions to the historical hydrograph (where available) or an estimated "natural, unimpaired" hydrograph (that is, the existing hydrograph adjusted for unnatural flow gains or losses resulting from the effects of storage, diversions, impervious surface runoff, etc.) describes the degree of hydrograph alteration from "normative" river conditions. In this context, "normative" refers to a flow regime that provides characteristics of flow magnitude, frequency, duration and timing essential to support diverse and productive salmonid populations (Independent Scientific Group 2000). Additional information on the use of flow alteration indicators and their meaning is described in two other sources. The Indicators of Hydrologic Alteration (IHA) method (Richter and others 1996) quantifies differences in IHA parameters between "before" and "after" flow regimes. The IHA analysis evaluates IHA parameters to explore changes and effects of watershed development on aspects of the flow regime that correspond to known ecological responses. Metrics to characterize the influence of urban development on storm flow and baseflow patterns have also been developed by the University of Washington's Center for Urban Water Resources Management (Conrad 2000).

A2: Floodplain Presence and Connectivity. The interconnection of an undisturbed stream channel and its floodplain area via periodic flood inundation provides several important functions essential for supporting diverse and productive salmonid populations. These functions include flow detention, groundwater-baseflow recharge, water quality filtration and the provision of side-channel and off-channel refuge and feeding habitats, particularly for rearing juvenile salmonids and native resident species. Two indicators are proposed for assessing floodplain connection: floodplain presence and floodplain inundation frequency. Floodplain presence is used to assess available floodplain presence and size based on typical valley width to channel width (VW:CW) ratios that would be expected under natural conditions according to channel type (Leopold and others 1992, Grant and Swanson 1995, Rosgen 1996). Floodplain inundation frequency is used to assess the frequency of flows that overtop channel banks into the floodplain. These flows provide the hydrologic link between off-channel habitats and the main channel, and they maintain floodplain wetland function and riparian vegetation and function.

A3: Groundwater. Groundwater plays a large role in maintaining the quality and quantity of water in stream and river ecosystems. It is an important source of summer baseflow and provides inputs of cool water that can moderate stream temperatures. Depending on the quality of groundwater relative to surface water, groundwater may either dilute or contribute pollutants to the stream environment. Groundwater also supplies hyporheic flows, which are important for successful salmonid spawning.

Groundwater presents difficulties as an indicator. Measuring the quantity and quality of groundwater entering a watershed is challenging, as is understanding groundwater's effects on the stream ecosystem. In this appendix, groundwater is listed as a potential indicator to emphasize its critical importance to the proper functioning of stream and river systems but with the realization that additional work is needed for groundwater to be practically measured and used in evaluating watershed health.

TABLE G-2
Hydrology Indicators and Metrics

Indicators	Metrics*
A1: Hydrograph Alteration	Peak flow Baseflow Seasonal patterns in hydrograph (such as mean monthly flows) Diel and tidal variability Percentage of the time that daily mean discharge exceeds annual mean discharge Coefficient of variation in the annual maximum flood
A2: Floodplain Presence and Connectivity	Area of historically connected floodplain/area of currently connected floodplain Frequency of overbank flow
A3: Groundwater	*[Groundwater metrics are under development.]*

*Metrics are the characteristics of an indicator that are measured to evaluate its condition.

Physical Habitat Indicators

Habitat quality and quantity are important determinants of the structure and function of riverine ecosystems (Frissel and others 1986) and of the health of the biological communities within them (Gregory and Bisson 1997). Aquatic habitats in urban and urbanizing areas such as Portland are more highly altered than in any other land-use type in the Pacific Northwest (Gregory and Bisson 1997). Activities and land use changes associated with urbanization significantly alter hydrology, soils and riparian vegetation in ways that can directly affect salmonids through modification or loss of riparian and instream habitats. Habitat can be altered by direct and indirect effects of human perturbations and/or by preventing natural processes from occurring (National Research Council 1996).

The fundamental building blocks of instream habitat are water, substrate, wood and energy (Naiman and others 1992, Washington Forest Practices Board 1995). The processes that supply these building blocks are supported by normative hydrology and floodplain connectivity, healthy riparian zones and good water quality. If these components are intact, the instream components of habitat that aquatic biota require—floodplains, pools and riffles, large wood and appropriate substrate—will be maintained by watershed processes.

The physical habitat indicators address the components of riparian zones that create and maintain habitat, the instream structures that make up physical habitat for aquatic biota and the factors that determine whether existing habitat is accessible. *Indicators for terrestrial and wetland habitat are under development.*

A4: Floodplain Quality and Connectivity. Floodplain presence and connectivity (described previously) emphasize the need to have intact and connected floodplains to, among other things, attenuate flows and moderate normative flows. However, floodplains also provide important habitats for salmon, such as overwintering habitat, refuge from high flows and feeding and rearing areas (Gregory and Bisson 1997). And floodplains contribute organic matter, substrate and large wood to the stream system. These important functions are associated with floodplain quality.

The floodplain quality indicator addresses the fact that floodplains must have proper physical structure and vegetation to provide these functions. In urban areas, the frequent development of floodplains results in extensive vegetation removal, increased numbers of nonnative species, conversion to impervious surfaces, alterations to landforms through excavation and filling, and soil contamination. These activities ultimately remove the floodplain components that provide valuable ecological functions.

A5: Riparian Condition: Width, Composition and Fragmentation. Riparian areas provide multiple functions that are essential for aquatic habitats and wildlife (Gregory and others 1991, Forest Ecosystem Management Assessment Team 1993, Castelle and others 1994). Riparian areas shade streams and moderate stream temperatures, provide overhead cover, filter sediments and runoff, and provide a terrestrial source of organic matter and insects that support aquatic food chains. Riparian areas also provide a source of large wood in channels and control streambank erosion and hillslope sediment production (mass-wasting) (Castelle and others 1994).

There is considerable variability in the definition of an "intact" riparian area. May and Horner (2000) state that important elements of riparian integrity include riparian corridor width, riparian corridor connectivity, vegetative composition and stand maturity. Notably, riparian width varies with local topography, geology and soils (see landscape factors, discussed earlier in this appendix) as well as the type and degree of human use (see human influences, discussed later in this appendix). Thus optimal riparian conditions vary depending on, among other factors, stream size, stream gradient, locale (headwaters vs. confluence), vegetation types and adjacent land use.

Generally, wider and more intact riparian corridors are more desirable than narrow and highly fragmented corridors. The width of the riparian corridor indicates the expanse of vegetative cover extending from both streambanks. This is important for shading the stream corridor and stabilizing streambanks, floodplains and hillslopes.

The composition, age and spatial structure of tree and shrub species are also important to consider when evaluating a riparian area's potential contributions to stream health. Different tree canopy coverages throughout the year encourage the development of different environs for riparian-dwelling species. Notably, the mixed conifer and deciduous forest stands that historically were common in upland habitats of the lower Willamette Valley remain important today. These forest types contribute significant pieces of wood to the stream channel, stabilize streambanks, provide leaf litter to the stream and generally maintain native vegetative communities. In contrast, forest stands dominated by deciduous trees and having few conifers make less significant contributions to the stream. Some deciduous trees are not adapted to aquatic fringe habitats the way certain conifers—such as western red cedar—are, and deciduous trees provide very different leaf litter and large woody debris to streams than conifers do. In addition, hardwoods generally decompose more quickly than conifers. The combination of these effects can significantly affect riparian condition and the benefits it provides to stream health.

A6: Stream Connectivity. Salmonids require a variety of connected habitat types and conditions throughout their lives. Adults need opportunities to migrate upstream and spawn, while juveniles and resident trout require opportunities to move while rearing to find food, avoid predators and seek unique habitat niches. Ideally these opportunities exist year-round, but they are especially important during fall/winter adult migrations, spring emigrations and summer low-flow conditions.

Stream connectivity is affected by natural and artificial features (usually hard and fixed) within and along the stream channel and conditions occurring in the stream. For example, culverts, dams, sewer lines and concrete walls can totally, partially or temporarily (usually seasonally) block fish passage via physical obstruction or by creating hydraulic or hydrologic conditions that impede fish movement. High-water velocities at a culvert inlet or outlet or within a culvert can overwhelm prolonged and burst swimming speeds, thus creating velocity barriers. Shallow water depths (less than 6 inches) within a culvert may limit a fish's ability to swim upstream or downstream, thus stranding or isolating it in specific stream reaches. Depending on the culvert design (high flow vs. low flow), stream flows may delay fish from accessing upstream and downstream sites at critical times and may distribute fish into less than ideal locations. Finally, the height between a culvert outlet and the water surface may exceed maximum jumping heights for salmonids, rearing trout or both.

Habitat breaks or altered boundaries that adversely affect a fish's migratory potential can impair a population's ability to persist and reproduce. Specifically, delayed adults may expend a great portion of their energy reserves, resulting in weakened fish that are more disposed to disease or prespawning mortality or, in females, retention of eggs. Additionally, eggs may be deposited during unfavorable environmental conditions for egg and fry survival; this can leave headwater areas poorly seeded while downstream reaches exceed their stream carrying capacity. In summary, the number, location and type of barriers in a watershed act as a filter that determines the amount of habitat available to each species and age-class of fish (Oregon Department of Fish and Wildlife 1999).

Channel Condition and Habitat Structure

Physical attributes and processes affecting habitat quantity and quality are often interrelated. For example, bank stability influences the amounts and types of substrate entering the creek bed, which in turn affect the amount and extent of silts overlaid on spawning beds. Vegetative composition and size significantly affect stream temperature and bank stability in the present, but they also influence the potential for large woody debris recruitment into the stream in the future. For practical purposes, the channel condition and habitat structure indicators presented below are discussed as discrete topics, but in actuality they are interrelated factors that interact to influence habitat formation and ecosystem dynamics. The indicators that reflect channel condition and habitat structure are as follows:

- Habitat types
- Bank erosion
- Channel substrate
- Off-channel habitat

- Refugia
- Large wood

A7: Habitat Types. The amount and type of habitat found in riverine systems affect the biotic potential of that stream. Stream structure and habitat sequencing (pool-riffle sequences vs. pool-glide-pool, for example) are major factors in determining habitat function. Salmonids require different physical environments, such as gravel and cobble habitats, deep pools and—for some species—slack water, throughout progressive stages of their life. Without an adequate amount and proportion of each, physical habitat can limit salmonid productivity within a subbasin.

Gravels and cobbles are predominate substrates in riffles and often in pool tail-outs. These habitats are important to salmonids during spawning, egg incubation, fry emergence and rearing. Additionally, they provide important substrata for production of epifauna and subsequently macroinvertebrates, which are a critical food source for aquatic biota.

Pools are particularly valuable refuge areas for juveniles and migrating and spawning adults in the winter and during storm events. In general, a variety of pool types is required to provide the range of habitat needed by different species and life stages throughout the year. Pools are important to rearing juvenile steelhead, Chinook and cutthroat, which reside and overwinter in deep pools, off-channel pools and slack water. In addition, fish seek deep pools for cover and refuge from predators. Some runs of adult salmon hold in deep pools en route to their natal stream and require deep areas to navigate past barriers such as cascades, falls, debris jams or culverts. Notably, adult spring Chinook hold in deep pools for several months between the time they enter freshwater and the time they spawn, which they also do in pools (of deeper than 0.24 meter). Additionally, some salmonids prefer deep habitats, at higher velocities; as an example, juvenile coho often prefer deep waters (0.3 meter to 1.2 meters) in submerged riffle habitats (U.S. Fish and Wildlife Service 1983). Pool frequency is assessed by the number of pools within a given distance of stream channel length. Under natural, undisturbed conditions, a fairly predictable relationship exists between channel type and the longitudinal distance between pools (Schuett-Hames and others 1994, Montgomery and Buffington 1993).

In addition to deep pools, slack and shallow water habitats are especially important for coho salmon, which often migrate to lower river reaches during their juvenile maturation and seek slack water, side channels or backwater pools in which to overwinter. These environs provide year-round food sources and cover and are generally devoid of other competing salmonids. Co-occurring steelhead, Chinook and cutthroat often overwinter in deep pools on mainstem or tributary reaches.

Gravel and cobbles, deep pools and slack and shallow water are not the only physical habitat types that influence salmonid population structure. The presence and area of other habitat forms, such as steps, cascades, rapids and glides, determine the spatial distribution of both anadromous and resident fish populations. Notably, steps, cascades and rapids can naturally impede fish from moving upstream and thus effectively isolate populations. In addition to these natural habitat forms, piped reaches impede fish passage and lessen the amount of natural creek bed, effectively limiting subsequent biotic production. Especially in urban streams, culverted creek reaches can make up a significant amount of instream habitat, thus limiting the carrying capacity or productivity that a system would be expected to support.

A8: Bank Erosion. Bank erosion is indicative of a system's ability to withstand erosive flows. Some erosion is natural and expected. However, when erosion is above what is considered normative, banks become unstable and excess sand, silt and organics fall into the waterway. Regular, severe infusions of bank materials into the creek often result in high concentrations of suspended and settleable solids that impair both habitat and water quality. Generally, areas where 30 percent to 60 percent of the streambank consists of bare soil, without root networks and possibly showing signs of sloughing, are considered moderately unstable and have a high potential for future erosion (Barbour 1999).

A9: Channel Substrate (Fine/Coarse). This indicator evaluates the proportion of boulders, cobbles, gravels, sand, silt and organic matter that make up the channel bottom. Gravels and small cobbles are critical for salmon spawning and incubation. The presence of excessive fine sediment in the interstitial spaces of gravels and cobbles (termed "embeddedness") can limit the amount of water—and thus dissolved oxygen—that reaches incubating salmon eggs. It also can impair fry emergence by creating a barrier over the substratum and preventing fry from reaching the water column, and it can limit juvenile rearing opportunities by covering the substratum and limiting the epifauna production and subsequent macroinvertebrate productivity that salmonids depend on. Boulders likewise provide important cover for salmonids and add roughness to a stream channel.

Salmonids require an array of substrate sizes (from 1.3 to 14 centimeters) to successfully spawn in, and consequently for eggs to incubate and fry to successfully emerge and rear. Bed materials cannot be embedded or extensively covered in fine silts and sediments. Rather, they must be relatively loose so that salmonids can successfully dig redds and lay eggs and the eggs can be exposed to adequate flows and oxygenation during incubation. Substrate permeability is critical to the development and emergence of salmonid fry.

Amassed fine sediment (meaning particles less than 0.1 inch in diameter) and extreme silt loads (greater than 25 milligrams per liter [mg/L]) (Bell 1973) can clog fish gills, affecting a fish's ability to absorb oxygen, and can also trap fry attempting to leave the gravel. Additionally, fine sediment covering cobbles and gravels reduces interstitial spaces that are used by aquatic invertebrates, a primary food source for salmonids. Excessive fine sediment content in rivers and streams, particularly in those channel types where such fine sediment content historically was not present, indicates possible sedimentation problems that are often associated with excessive runoff or hillslope and channel erosion.

A10: Off-Channel Habitat. Side channel and off-channel habitats are important feeding, resting and rearing areas and, by providing protected areas with lower flow velocities, serve as key refugia during flood events. Off-channel habitats may provide spawning areas for coho and chum salmon (Cederholm and others 1988, Samuelson 1990), rearing and overwintering areas for many species (a number of studies summarized in Keeley and others 1996) and year-round residence for cutthroat and several non-salmonid fish species (Cederholm and Scarlett 1981, Peterson 1982). Survival in off-channel areas can be at least twice as high as in mainstem habitats during the winter period (Bustard and Narver, 1975). Numerous investigators have shown that coho salmon have strong preferences for off-channel habitats (Everest and others 1985, Glova 1986, Taylor 1988, Bugert and Bjornn 1991), and Nickelson and others (1992) found that elimination of off-channel rearing areas was a significant limiting factor in coho production in coastal streams. In addition, off-channel overwintering ponds have been shown to be one of the most effective types of salmonid enhancement (Cederholm and Scarlett 1988).

A11: Refugia. Streamside vegetation, undercut banks, boulders, turbulent areas, deep pools and large pieces and clusters of wood provide physical refuge to salmonids. These environs provide important rearing habitat, shelter during high flows, cool water refugia when water temperatures are high and protection from predators. The amount, type and location of instream cover play an important role in salmonids' selection of habitat for spawning and rearing (U.S. Fish and Wildlife Service 1983).

In contrast, in large rivers it is often the lack of shallow water habitats that limits salmonid productivity. Dredging, channelization and the elimination of off-channel habitats have greatly reduced the amount of shallow water habitat in large, low-gradient rivers (City of Portland Endangered Species Act Program 1999). Shallow water provides important rearing habitat for juvenile salmonids (Levy and Northcote 1982, Brown and Hartman 1988) and refuge from larger aquatic predators.

A12: Large Wood. Large wood is one of the most important structural components in forming and maintaining salmon habitat (National Research Council 1996). A number of reviews have concluded that large wood provides a wide range of functions in physical habitat formation, including pool creation, storage of sediment and organic matter and maintenance of a high degree of habitat complexity in streams (Harmon and others 1986, Bisson and others 1987, Gregory and others 1991). Wood in large rivers has an important effect on local channel hydraulics and provides refugia by contributing to the formation of pool and side-channel habitats along channel margins (Abbe and Montgomery 1996, Bisson and others 1987).

TABLE G-3
Physical Habitat Indicators and Metrics

Indicators	Metrics
A4: Floodplain Quality and Connectivity	Vegetative composition of floodplain Amount of fill in floodplain Number of artificial structures in floodplain Ecological risk assessment of contaminants in floodplain Valley width index Stream gradient Entrenchment ratio Land use
A5: Riparian Condition: Width, Composition and Fragmentation	Width of vegetated zone Species composition (grasses, shrubs and trees), age structure and percentage of tree canopy cover within the riparian area Percentage of native vegetation Number of breaks per reach length Impervious area Bank condition (hardened, landscaped, natural form)

TABLE G-3
Physical Habitat Indicators and Metrics

Indicators	Metrics
A6: Stream Connectivity	Number and impact (totally impassable, partially impassable or temporarily impassable) of culverts or other natural and artificial hydraulic breaks (waterfalls, stormwater pipes, flood control structures, etc.)
A7: Habitat Types	Proportion of wetted area composed of pools, glides, riffles, cascades, rapids, steps and piped creek beds Pool quality (percentage of pool area or frequency, residual pool depth and pool complexity) Riffle quality (percentage of riffle area and substrate composition)
A8: Bank Erosion	Percentage of bank actively eroding Bank slope
A9: Channel Substrate (Fine/Coarse)	Substrate size and composition (boulders, cobbles, gravels, sands, fines and organics) by habitat type Embeddedness Turbidity (total suspended solids, or TSS)
A10: Off-Channel Habitat	Currently accessible tributaries/historically accessible tributaries Number of stream miles with secondary channels Area of “off-channel” habitat per mile
A11: Refugia	Number of pools per mile (could be broken out by pool types) Evaluation of pool quality Frequency distribution of depths Area of shallow water (less than 20 feet for large rivers) Percentage of undercut bank Percentage of substrate composed of boulders (in pools) Evaluation of large wood
A12: Large Wood	Number and size distribution of wood pieces per 100-meter stream length Wood volume per 100-meter stream length Key pieces per 100-meter stream length

Water Quality Indicators

Urbanization markedly degrades water quality. Stormwater runoff and combined sewer overflows can discharge nutrients and toxic contaminants from roadways and other surfaces into waterways (Novotny and Olem 1994), while point and nonpoint source discharges and removal of riparian vegetation can substantially increase nutrient and thermal loadings to waterways. Construction activities also can impair water quality via sedimentation. Nearly all of the watersheds in Portland fail to meet their designated beneficial uses (defined by the federal Clean Water Act) because of degraded water quality. The indicators proposed for this category were developed to reflect components of water quality that threaten stream health.

A13: Water Temperature. Temperature affects the survival and growth of stream biota. Increases in temperature can alter metabolism and behavior, reduce survival and reproductive success, and increase susceptibility to diseases and parasites (Poole and others

2001*)*. Increases also can alter the composition and productivity of stream communities and thus alter food supply and species' interactions with competitors and predators (Beschta and others 1987, Bjornn and Reiser 1991). None of Portland's watersheds meet State of Oregon temperature standards during summer months.

A14: Dissolved Oxygen (DO). Oxygen is a critical component in the functioning of healthy aquatic ecosystems. It plays an important role in making energy available for biological processes, and biota within streams and rivers require it for respiration. Microorganisms require oxygen for oxidative processes important in breaking down organic matter and other key processes. In addition, a number of critical chemical processes, including the adsorption and release of pollutants in sediments, are strongly affected by the presence of oxygen (Strobel and Heltshe 2000).

Salmon, which are particularly sensitive to oxygen concentrations, require high levels of dissolved oxygen. Low levels of oxygen (less than 6.0 mg/L) impair the growth and development of embryos and fry and the swimming ability of migratory adults and juveniles (Bjornn and Reiser 1991).

Most monitoring efforts collect data on dissolved oxygen in the water column. This provides important information on the suitability of conditions for salmonids, but it is important to realize that, because oxygen solubility in water is limited, oxygen concentrations can vary greatly through the water column in streams and rivers that are not well mixed. The location at which oxygen data are collected has a large effect on the results. In fact, oxygen concentrations at the interface of substrate and water may be considerably lower than concentrations in the water column (Prescott, unpublished data). Salmon eggs and alevin are highly sensitive to oxygen concentrations, and it may be necessary to gather data on intergravel dissolved oxygen to accurately reflect the conditions to which salmon eggs and alevin are exposed.

A15: Nutrients and Chlorophyll a. Evaluation of nutrients and chlorophyll *a* illuminates the production dynamics of aquatic ecosystems and can indicate when nutrient and production levels become excessive as a result of inputs from human activities. Excessive nutrients can have adverse effects on aquatic ecosystems. For example, nitrite-nitrogen can be toxic to rainbow trout, and ammonia is toxic to aquatic invertebrates and fish (U.S. Environmental Protection Agency 1986). In addition, high levels of nitrogen and phosphorus compounds may result in eutrophication, wherein algal growth is stimulated to the point that high levels of algal respiration reduce dissolved oxygen levels.

A16: Total Suspended Solids (TSS). Total suspended solids have been selected as an indicator because measures of TSS and turbidity can provide important information about two critical components of watershed health: sediment supply and contaminant dynamics. Human activities that alter sediment supply and dynamics can have far-reaching impacts. Changes in sediment supply can harm habitat for fish and aquatic organisms (see the channel substrate indicator); affect the shape, sinuosity and pool-riffle structure of streams; and have direct physical impacts on aquatic organisms (U.S. Environmental Protection Agency 1991). In addition, because many nutrients and toxic contaminants sorb strongly to sediment particles, runoff of sediments from urban land uses can be a significant pathway by which these contaminants are introduced to the aquatic ecosystem (Novotny and Olem 1994).

A17: Toxic Contamination of Water, Sediments and Biota. Urban areas have the potential to contribute metal and organic contaminants to streams and rivers in amounts that are toxic to aquatic organisms. A number of studies have identified adverse impacts of toxic contaminants on aquatic ecosystems (U.S. Environmental Protection Agency 1983, Meyers and others 1985, Novotny and Olem 1994). Many of these contaminants are hydrophobic and adhere strongly to sediments or bioaccumulate within the tissues of aquatic organisms. Nationwide, the toxic contamination of sediments and organisms is pervasive and in many urbanized areas severe (U.S. Environmental Protection Agency 1997).

Toxic contaminants can directly affect the health of salmonids. Juvenile salmon migrating through urban areas with contaminated sediments may have reduced growth and survival rates and be more susceptible to disease (Varanasi and others 1993) than juveniles migrating through areas without contaminated sediments. Locally the issue of toxic contaminants is an important indicator for restoration because the Portland Harbor area has high concentrations of contaminants known to affect salmon and other aquatic organisms (U.S. Environmental Protection Agency 1998).

A18: Groundwater Quality. As mentioned earlier, groundwater is an important component of stream health, although its effects on the stream ecosystem are difficult to quantify accurately. To the extent possible, the role of groundwater in contributing pollutants—or in providing clean water that dilutes stream contaminant concentrations—should be evaluated.

A19: Other 303(d)-listed TMDL Parameters. The 303(d) list is a list of stream segments that do not meet their designated beneficial uses as defined by the federal Clean Water Act and that have parameters that fail to meet the act's water quality standards. Because many of the designated uses of a waterbody are ecological, the 303(d) list is helpful in identifying water quality attributes that are impairing the ecological health of a watershed. Any 303(d)-listed total maximum daily load (TMDL) parameters not captured by the indicators above should be used as indicators for the health of the watershed.

A20: Other Parameters (as determined by the weight of evidence). Some important contaminants are not addressed by water quality standards. Diazinon, for example, is a pesticide commonly used in urban areas that does not have a water quality standard in Oregon yet has the potential to affect watershed health (Scholz and others 2000). In addition, the complex fate and transport of many organic contaminants in the environment may mean that these contaminants are poorly addressed through existing sediment and water quality standards. For example, emerging research by NOAA Fisheries' Montlake Research Laboratory is finding that fish are adversely affected by polycyclic aromatic hydrocarbons (PAHs) at concentrations below existing standards (Johnson 2000). Where the weight of evidence (biological monitoring, pesticide use studies, emerging research, etc.) indicates that contaminants that are not on the 303(d) list have significant adverse effects on biological communities or ecological functions, those contaminants should be tracked and evaluated as indicators.

TABLE G-4
Water Quality Indicators and Metrics

Indicators	Metrics
A13: Water Temperature	Mean 7-day maximum *[A metric also needs to be developed to reflect localized variation in temperatures and the presence of thermal refugia (for example, the number, spatial distribution and flow of groundwater seeps).]*
A14: Dissolved Oxygen	mg/L DO Percent saturation Intergravel DO
A15: Nutrients and Chlorophyll *a*	mg/L of ammonia, nitrogen (nitrate + nitrite), total phosphorus, orthophosphate and chlorophyll *a*
A16: Total Suspended Solids	mg/L TSS Turbidity
A17: Toxic Contamination of Water, Sediments and Biota	Area with contaminant levels exceeding risk-based effects thresholds Number of species with tissue contaminant levels exceeding the risk-based effects thresholds
A18: Groundwater Quality	The parameters above applied to groundwater inputs
A19: Other 303(d)-listed TMDL Parameters	Determined by listed parameter
A20: Other Parameters (as determined by the weight of evidence)	Specific to parameter

Biological Communities Indicators

A21: Biotic Integrity. Biotic integrity has been defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a composition, diversity and functional organization comparable to that in the natural habitats of the region (Frey 1977). A widely used indicator of the integrity of fish communities—and human impacts on them—is the index of biotic integrity, or IBI (Karr and others 1986). Specifically, the IBI reflects important components of an ecosystem, such as taxonomic richness (the number of native families and native species present), habitat guilds (benthic species, native water column species, hider species, sensitive species, nester species and the proportion of tolerant individuals), trophic guilds (the percentages of filter-feeding individuals and omnivores) and individual health and abundance (the percentages of target species and individuals with anomalies). Fish surveys can be queried to derive an IBI rank and subsequent description of biotic integrity.

In addition to absolute IBI scores and what that implies in terms of biotic impairment, data on the presence or absence of fish can be evaluated to determine relative water quality condition, based on an individual family's tolerance for silty, warm and polluted waters. Salmonids tend to be sensitive to water quality conditions, while nonnative species tend to be tolerant of degraded water quality. For example, common carp are omnivorous, are exceptionally tolerant of warm, turbid, silty water and are indicators of seriously degraded habitat conditions (Mebane and others 2003).

A22: Benthic Communities. Biological communities that spend the majority of their life cycle in local watersheds, such as benthic macroinvertebrates, can supplement salmon as a reflection of local conditions. Benthic macroinvertebrates have been used extensively in assessing the chemical, physical and biological health of watersheds and in assessing cumulative effects (see, for example, Karr and Chu 1999). The City of Portland and Portland State University are in the process of developing biological indices for local watersheds that use benthic macroinvertebrates and algal community composition. The metrics that arise from this effort will be used as indicators of biological communities. These and other metrics will be more fully described and justified as the City of Portland and Portland State University work is completed.

Ephemeroptera-plecoptera-trichoptera (EPT) taxa are sensitive macroinvertebrate species that are often used as indicators of macroinvertebrate production and coarse-level stream health. Notably, the number or proportion of EPT taxa are thought to decrease as environmental perturbations increase.

Algae (attached periphyton) also have been used successfully as indicators of stream conditions (Stevenson and Pan 1999) because they have short generation times and they respond rapidly to a variety of physical and chemical variables such as nutrients (Pan and others 1996), pH (Pan and others 1996) and herbicides (Hoagland and others 1996). Algae often are the first group of organisms to respond to both environmental degradation and recovery. In addition, using indicator species at a variety of trophic levels (meaning levels within the food web) can provide insight into energy sources and flows through the ecosystem.

A23: Salmonid Population Structure. Legally, culturally and ecologically, salmon are important indicators of the health of a watershed. In *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany and others 2000), NOAA Fisheries defines four key population attributes that are important to assess in restoring salmon:

- Abundance. Also referred to as population size, abundance is an important measure of a population's health and fitness at various life stages. All else being equal, small populations are at greater risk of extinction than large populations because they have less buffering capacity to withstand severe environmental change or catastrophic loss. Simply put, in large populations, more individuals are likely to remain to repopulate an area after a loss. Viable populations should be large enough to adapt over time to environmental variation, genetic variation, demographic stochasticity and catastrophic events, while maintaining a healthy population.
- Productivity. Also referred to as population growth, productivity provides information on how well an individual population is performing (for example, the number of returning adults produced by the parent spawner) in response to its environment. A salmonid population's natural productivity should be sufficient to maintain its abundance above the viable level in the absence of hatchery fish, during poor ocean conditions and across multiple generations.

- **Spatial Structure**. Spatially structured populations are often referred to as metapopulations. According to McElhany and others (2000), "a population's spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution." Spatial structure depends on habitat quality, spatial configuration, dynamics and dispersal behaviors.
- **Diversity**. Salmonids exhibit diverse life history traits within and among populations that affect population viability and persistence. Diversity allows a species to inhabit varying environs, protects a species against short-term catastrophic loss and provides the genetic make-up to allow the species to persist through long-term environmental change. Specific life history traits include anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age structure, size, developmental rate, ocean distributions and molecular genetic characteristics (McElhany and others 2000).

To be consistent with the guidance in *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany and others 2000), the City of Portland's Endangered Species Act Program will be tracking these same parameters in local populations and is developing fish monitoring programs that focus on these parameters.

A24: Species Interactions. Species interactions determine the balance among populations of competitors, pathogens, predators and prey and play a critical role in regulating the composition and function of natural communities. Human activities have altered the balance of many species' interactions both directly and indirectly—directly through the introduction of exotic species that prey upon or compete with native species (Li and others 1987) and indirectly through changes in habitat that alter pressures from predation or competition (Reeves and others 1987). Evaluating the composition, relative abundance and spatial distribution of native and nonnative species over time will provide a means of evaluating changes in species interactions over time.

A25: Riparian Wildlife. Riparian areas are more biologically productive than any other natural environment, aquatic or terrestrial. The aquatic fringe habitats that characterize riparian areas contain a variety of vegetative species; these species have very different functional values that are adapted to both terrestrial and aquatic or wetland ecosystems. These unique habitats provide important rearing habitats and refuge to terrestrial and aquatic-dwelling species, as well as migratory wildlife. Wildlife use these areas for nesting, rearing, temporary refuge and feeding. As stated by Puchy and Marshall (1993), "if amphibian, reptile, bird and mammal numbers are combined, riparian areas support more species than any other community type" in Oregon. Riparian areas provide habitat for birds and mammals (Castelle and others 1994, Kauffman and others 2001) and herpetofauna (Kauffman and others 2001).

Presuming that wildlife are useful indicators of watershed health, specific indicator or keystone species for riparian wildlife should be chosen. These should include wildlife indicator species that represent the major wildlife guilds that inhabit riparian ecosystems. Species occupying or using both aquatic and terrestrial habitats in their life history expression will be selected as riparian wildlife indicator species.

The primary ecological principles and the riverine, wetland and upland ecology principles presented in Chapter 2 of this *Framework* are relevant to riparian wildlife. However, the City of Portland has yet to identify potential indicators of riparian wildlife health. Until these indicators are developed, riparian conditions can be evaluated to determine whether they are consistent with high, moderate or low riparian quality and wildlife value. In other words, if the riparian corridor is broad and intact (with few breaks), tree canopy cover and shrub cover are relatively high, the species composition is consistent with habitats and vegetative types of the Pacific Northwest, and stand structure provides horizontal and vertical structure (stand age), then the riparian area presumably has the potential to provide some wildlife value. The City intends to select indicator riparian wildlife species for individual watersheds once characterization has been completed.

A26: Terrestrial Wildlife. Because watersheds are geographically defined from ridgetop to ridgetop, achieving and maintaining healthy watershed conditions and functions must address terrestrial as well as aquatic and riverine species and habitats (see Riverine, Wetland and Upland Ecology Principle 1). If wildlife are to be useful as indicators of watershed health, specific indicator or keystone species must be chosen. The selection of indicator species makes apparent the life histories and thus specific habitats and ecosystem functions that are required for healthy populations of the indicator species and associated species with similar habitat needs. Ideally, a manageable set of wildlife indicator species would be identified that represents the major guilds present in the terrestrial ecosystem. The protection and restoration of these species and their habitats would also provide protection for the suite of species present in the terrestrial ecosystem. The City of Portland is in the process of determining how it will select indicator species for terrestrial wildlife in individual watersheds following characterization. Information developed for Tables E-1 and E-2 in Appendix E will be evaluated during this process.

A27: Plant Communities. Healthy plant communities serve many important functions: they provide habitat for native wildlife and preserve critical habitat for rare, threatened and endangered animals and plants; enhance air and water quality by trapping airborne particulates and filtering sediments and pollutants from runoff before they enter streams and aquifers; stabilize streambanks and hillside slopes and dissipate erosive forces; ameliorate the local microclimate and reduce water and energy needs; and provide scenic, recreational and educational values which, in turn, enhance Portland’s livability.

The City of Portland has not yet selected specific indicators and metrics for plant communities for use in watershed planning as described in this *Framework*. The City is in the process of determining how it will select indicator species for plant communities in watersheds following characterization. In the interim, the City of Portland has adopted a native plant policy that is designed to ensure the continued viability and diversity of indigenous plant communities, to promote the use of plants naturally adapted to local conditions, and to educate citizens about the region’s natural heritage and the values and uses of native plants. In support of this policy, the City compiled the Portland Plant List, which now serves as an integral component of the City’s natural resource protection program (see http://www.planning.ci.portland.or.us/lib_plantlist.html). Native plants identified on the list are required within the City’s Environmental and Willamette River Greenway Zones, and invasive or harmful plants (identified on the “Nuisance” or “Prohibited” plant lists) are prohibited. The list is organized according to general habitat types, including wetland, riparian, forest (upland forested areas with little or no slope), forested slopes (steeply sloping upland forest), thicket (edges of forests and meadows), grass (open areas or meadows) and rocky upland areas. The list indicates which plant species are found within each of these habitat types. The list further divides plants into three groups: trees and arborescent shrubs, shrubs, and ground covers.

TABLE G-5
Biological Communities Indicators and Metrics

Indicators	Metrics
A21: Biotic Integrity (fish community structure)	Index of Biotic Integrity (IBI), Benthic Index of Biotic Integrity (B-IBI) and other community metrics (species richness, percentage of intolerant taxa, etc.)
A22: Benthic Communities	EPT Algal community composition
A23: Salmonid Population Structure	Abundance Productivity Spatial structure Diversity Presence/absence
A24: Species Interactions (predation, competition, exotic species, etc.)	Native/exotic ratio Number of exotic predators and competitors Relative abundance and spatial distribution of predators and competitors
A25: Riparian Wildlife	*[Metrics for riparian wildlife have yet to be developed. In the interim, riparian conditions such as width and intactness of the riparian corridor, tree canopy cover, species composition and stand structure can be evaluated.]*
A26: Terrestrial Wildlife	*[Indicator or keystone species have yet to be selected and metrics developed.]*
A27: Plant Communities	*[Indicators and metrics for plant communities have yet to be developed. In the interim, the City's native plant policy and Portland Plant List will be employed as appropriate.]*

Links Between Potential Watershed Health Indicators and Ecological Functions

As described at the beginning of this appendix, indicators are merely surrogates of underlying ecological functions that maintain watershed health. They are measurable reflections of complex ecological processes that can be difficult to measure directly. It is important to remember, however, that it is the integrity of the ecological processes that is ultimately required to restore and maintain watershed health. The City of Portland will use indicators to evaluate the degree to which ecological processes are functioning properly and as "useful signals of environmental degradation" (Bisson and others 1997).

Table G-6 identifies some of the key ecological functions that maintain watershed health and some of the potential indicators that will be used to directly or indirectly evaluate the nature and dynamics of those functions. The listed functions are a summary of watershed functions identified by the Federal Interagency Stream Restoration Working Group (1998) and the City of Portland (2001).

Human Influences

Human influences are predictive or stress-oriented indicators, as described by the National Research Council (1995). These indicators point to the sources of the problems that are revealed through evaluation of the watershed health indicators. Indicators of human influences also aid in the identification of solutions and opportunities. Essentially, the purpose of the human influences indicators is to identify the stressors on the ecosystem and, to the extent possible, begin to provide information on cause-and-effect relationships between impacts and their potential sources.

For example, human activities and landscape alterations can greatly increase rates of erosion and sediment transport to the point that stream habitat and water quality are adversely affected. Specifically, removal of vegetation, construction activities and soil-disturbing land uses alter soil properties on the landscape and can result in loss of soil or soil compaction.

In addition to land-disturbing activities, changes in the way water flows across the landscape can increase the amount of sediment delivered to streams. Loss of wetland habitats, increases in impervious surfaces and the piping of stormwater runoff directly into waterways eliminate opportunities for stormwater to infiltrate through the subsurface, which naturally removes and stores sediments. Increased amounts of sediment delivered to a waterway can then degrade aquatic habitat, destroy spawning areas, harm fish and other aquatic organisms and result in incised (and unstable) channel condition. In addition, sediments—particularly fine sediments—are a primary carrier of many of the pollutants so common in the urban landscape, such as metals, nutrients and toxic organic compounds (Novotny and Olem 1994).

Characterizing indicators of human influences and urban activities can help identify sources that may impair watershed health, and monitoring these indicators can identify emerging issues before they become problematic to ecosystem functions. The indicators of human influences are described below. The link between each indicator and its impact on components of watershed health is described generally under each indicator and in Table G-7.

B1: Land Use. Land use is a general indicator of the types of human activities that occur across a landscape. In a sense, land use is a catchall indicator that integrates a number of human activities and impacts. Impacts that are strongly associated with land use include impervious surfaces (U.S. Department of Agriculture, Natural Resources Conservation Service 1986; May and others 1997), vegetative characteristics (May and others 1997) and stormwater pollutant concentration (U.S. Environmental Protection Agency 1994). Land use may directly or indirectly affect all four categories of indicators of watershed health: watershed hydrology, physical habitat, water quality and biological communities.

TABLE G-6
Links Between Potential Watershed Health Indicators and Key Watershed Functions

	Indicators																									
	Hydrology			Physical Habitat								Water Quality								Biological Communities						
Watershed Functions	Hydrograph Alteration	Floodplain Presence and Connectivity	Groundwater	Floodplain Quality and Connectivity	Riparian Condition	Habitat Types	Bank Erosion	Channel Substrate	Off-Channel Habitat	Refugia	Large Wood	Water Temperature	Dissolved Oxygen	Nutrients and Chlorophyll a	Total Suspended Solids	Toxic Contamination	Groundwater Quality	303(d) Parameters	Other Parameters	Biotic Integrity	Benthic Macroinvertebrates	Instream Communities	Salmonids	Species Interactions	Riparian Wildlife	Terrestrial Wildlife
Groundwater Recharge and Storage			●																							
Baseflow	●		●																							
Flood Storage and Attenuation		●																								
River/Floodplain Interaction		●		●					●																	
Channel Composition and Dynamics					●	●	●	●		●	●									●						
Structural Complexity					●	●		●		●	●									●						
Habitat Connectivity		●		●	●	●														●						
Refugia		●				●			●	●	●									●						
Shading and Microclimate			●		●						●	●														
Sediment Transport and Storage		●					●	●			●				●						●					
Food Web (primary and secondary production, feeding, respiration, decomposition)		●		●																●	●	●	●	●	●	●
Organic Inputs		●		●	●																●					
Temperature					●							●					●	●		●						
Nutrient Cycling		●		●	●									●			●	●		●						
Oxygen													●				●	●		●						
Toxics																●	●	●	●	●						
Pathogens																	●	●		●					●	
Reproduction																				●		●	●	●	●	●
Growth																				●	●	●	●	●	●	●
Survival																				●		●	●	●	●	●
Species Interactions (competition, predation)																				●		●	●	●	●	●

B2: Impervious Surfaces. Impervious surfaces are an important indicator for two reasons:

- **They have a direct impact on watershed hydrology and health.** As one of the key sources of degradation from urban development, impervious surfaces affect flow, water quality, temperature and stream habitat (Schueler 1994).
- **They are a general indicator of human development.** Within urban land uses, nearly all types of human development or activities are associated with impervious surfaces. Beyond their flow and habitat impacts, impervious surfaces are also a general indicator of the intensity and spatial distribution of human development and activities and can integrate cumulative effects from a complex range of activities and impacts (May and others 1997).

Clearly, tracking impervious surfaces as an indicator treats all urban land uses equally and does not capture the diversity of activities and impacts associated with various land uses. However, the amount of impervious surfaces is a good general indicator of human impacts and has been used effectively in a number of studies of urban impacts (for example, May and others 1997).

Two measurements are proposed to evaluate this indicator: effective impervious area and total impervious area. Effective impervious area focuses on the hydrologic and water quality impacts of impervious areas. It accounts for the fact that the hydrologic and water quality effects of impervious areas may be partially ameliorated by hydrologically "disconnecting" the impervious surface from the stream by routing pipes through infiltration and detention facilities such as sumps, detention ponds and infiltration basins. Thus not all impervious surfaces have the same impact on hydrology, and this measurement attempts to account for best management practices that reduce the hydrologic and water quality impacts of impervious surfaces. Total impervious area, on the other hand, addresses the second element described above; namely, that impervious surfaces—regardless of whether they discharge directly to streams—are associated with human development and its potential to affect habitat and water quality.

The City acknowledges that, while valuable, impervious area is an imperfect indicator of watershed health. For this reason the City will also attempt to track the effectiveness of various management activities aimed at mitigating the impacts of impervious area. For example, infiltration swales, eco-roofs, constructed wetlands, sumps and other techniques mitigate the effects of impervious area. The City will attempt to account for situations where impervious area drains to these types of facilities.

Impervious surfaces directly affect stream flow, hydrology and water quality; through these impacts they affect physical habitat and biological communities.

B3: Dam Impacts. As described in Riverine, Wetland and Upland Ecology Principle 3, dams fundamentally alter the flow, habitat, water quality and biota of riverine ecosystems. Dams are present on virtually every major river in the lower 48 states, and the structure and function of regulated rivers are fundamentally different from those of free-flowing rivers. When dams are present, natural cycles of flooding and the transport of sediment, gravel and other materials are greatly reduced, and channel shape, vegetation and instream biological communities are fundamentally altered (Collier and others 2000). Dams can also block migratory salmons' access to habitat if proper passage facilities are not provided, and salmon may suffer increased mortality and injury even when passage facilities are provided (National Marine Fisheries Service 1996). Dam impacts affect all four categories of watershed health indicators.

B4: Water Withdrawals. The impacts on the health of streams and rivers of removing water for purposes of landscaping, irrigation and water supply include increased water temperatures, increased sedimentation, decreased gravel recruitment, dewatering of previously productive habitat, crowding and increased competition, and reduced productivity (Gregory and Bisson 1997). For salmon, lower baseflows can also increase vulnerability to predation, delay migration, increase stranding and result in the entrainment of juveniles into poorly screened or unscreened diversions (National Marine Fisheries Service 1996). Water withdrawals affect all four categories of watershed health indicators.

B5: Drainage Network. Within the urban landscape, many stream reaches and wetlands have been piped and diverted to allow development on top of former waterbodies and wetlands. This results in direct destruction of aquatic habitats and affects the hydrology of the watershed. For example, in Johnson Creek, 38 percent of former surface waters have been piped (Prescott in prep.). At the same time, development of stormwater drainage systems has dramatically altered the way precipitation flows through the watershed. Prior to development, precipitation predominantly infiltrated into subsurface soil and groundwater zones (Satterlund and Adams 1992). What little surface runoff occurred flowed through vegetation before reaching the stream. In the urban area, a significant portion of precipitation now falls on impervious surfaces (which preclude infiltration), generating stormwater runoff that collects contaminants accumulated on these surfaces; this stormwater is delivered into stormwater drainage systems in far greater volumes than previously. In addition, flow through this artificial drainage network does not provide any of the natural treatment processes that occurred when surface runoff flowed over natural soils and vegetation. The majority of urban runoff, with its associated contaminants from the farthest reaches of the watershed, is routed directly to the stream, with no treatment. The replacement of natural drainage systems with piped drainage systems has had dramatic negative impacts on aquatic ecosystems (May and others 1997). The drainage network affects all four categories of watershed health indicators.

B6: Channel Alterations. Human development has significantly altered the structure and function of stream and river channels. Bank hardening, channelization, channel maintenance (such as the removal of large wood), culverts and other stream crossings, and other channel alterations have the following effects:

- They prevent the stream and river from adapting to flow conditions. Rivers and streams normally are highly dynamic environments that change their form in response to variable flow conditions and in the process help form and maintain stream habitat. Structures that attempt to confine a stream into a particular configuration preclude the ability of the stream to adapt to variable flows and impede habitat formation and maintenance.
- They can prevent or decrease the interaction of a river with its floodplain.
- They can create impediments or barriers for salmonids migrating upstream, either in the form of physical constraints or as unsuitable velocities and flows. In these cases,

salmonids can be prevented from using otherwise suitable spawning and rearing habitats. Oftentimes some of the highest quality habitat (for example, Oaks Bottom, Forest Park, and Smith and Bybee lakes) is inaccessible to salmon as a result of culverts, weirs and other instream structures.

- They reduce instream habitat complexity, increase water velocity, degrade instream pool and riffle structure and eliminate large wood.

Channel alterations affect all four categories of watershed health indicators.

B7: Vegetation Management. As described in Riverine, Wetland and Upland Ecology Principle 1, rivers cannot be separated from the lands they drain. This means in part that vegetation and wetlands throughout the watershed affect the quantity and quality of water draining off the land. Evaluating urban impacts on watershed hydrology is more complicated than merely quantifying the amount of impervious surfaces and piped drainage systems. In forested watersheds, very little precipitation reaches the stream through surface runoff because of high rates of evapotranspiration and soil infiltration into organic soils (Satterlund and Adams 1992). Urbanization, on the other hand, often results in vegetation removal and soil compaction (Schueler 1995), which greatly increase the amount of runoff even from areas where pavement and other impervious surfaces are not present. Surfaces such as lawns and parks do not have the density of trees or forest duff layers needed to capture and infiltrate the vast majority of precipitation. In addition, urban lawns and other vegetated areas are often maintained with fertilizers, herbicides and insecticides, which have the potential to contribute to water quality problems. The vegetation removal associated with urbanization affects all four categories of watershed health indicators.

B8: Wetland Alteration. Wetlands throughout a watershed provide stormwater retention, groundwater infiltration, sediment filtration and pollutant removal (Reinelt and Horner 1995). As wetlands are filled and developed, the amount of surface runoff from the watershed increases and the quality of that runoff decreases. Wetland alteration affects all four categories of watershed health indicators.

B9: Outfall Discharges. Intensive land uses in urban areas produce a large amount and variety of pollutants. Road runoff, municipal and industrial processes, construction, erosion, fertilizers and pesticides, deposition of atmospheric contaminants, maintenance and other activities produce a broad range and high concentration of contaminants, including heavy metals, nutrients, particulates, organic contaminants, pathogens, oxygen-demanding substances and heat loads. Many of these contaminants are transmitted to streams and rivers by public and private stormwater outfalls, combined sewer overflows and point source process discharges. Thus, outfall discharges represent discrete points at which the variety of pollutants produced by land uses are introduced into urban streams and rivers. Identifying the location of these outfalls and characterizing the loads they contribute to aquatic environments will provide key information about the impact of urban land uses on water quality. Outfall discharges affect watershed hydrology and physical habitat on a local scale and can have broader effects on water quality and biological communities.

B10: Exotic Species. Some of the most severe effects of human activities on the world's biological communities have resulted from the introduction of exotic organisms (Suter 1993). Human development in and near the riparian zone and in many upland areas has resulted in the release of domestic animals such as dogs and cats and the introduction of invasive plant species such as Himalayan blackberry, reed canary grass and English ivy. The aggressive nature of these plants has dramatically altered the species composition and habitat values provided by riparian areas. Free-roaming domestic and feral cat populations have an impact on native wildlife, especially birds, while many wetlands are overpopulated with feral domestic ducks and geese. In addition, some sensitive riparian areas have become destinations for dogs that are off leash.

Past fisheries management practices also have resulted in the introduction of a large number of exotic fish species into local aquatic ecosystems. For example, of the 39 total fish species in the lower Willamette River, 19 have been introduced (Farr and Ward 1993). Introduced species include predators such as largemouth bass *(Micropterus salmoides)* and walleye *(Stizostedion vitreum vitreum)* and a large number of competitors tolerant of warm waters and altered habitat conditions. The presence of these introduced species may increase competitive pressures on native species.

Tracking the percentage of invasive species in riparian and aquatic communities is an important component of evaluating the integrity of the riverine-riparian ecosystem and tracking the success of restoration efforts. However, it is also important to exert effort toward tracking and preventing introductions of new species, including invertebrate species. For example, the introduction of green crabs (*Carcinus meanas)* and mitten crabs (*Eriocheri* spp.) has dramatically altered biological communities in California (Cohen and Carlton 1995). These species have not yet been observed locally, but an isolated individual mitten crab was found in the Columbia River. Exotic species affect physical habitat (by way of invasive vegetation) and biological communities.

B11: Harassment. The intensity of activities close to rivers and streams in urban areas has the potential to disturb and disrupt salmon. Lights from docks, bridges and other sources; noise from boat traffic, in-water construction and other urban activities; and the close physical presence of humans along trails and at homes and waterfront facilities all have the potential to adversely affect salmon behavior during spawning, feeding and migration. Although the specific effects of harassment on salmon have not been well studied, harassment is included as an indicator of human activity because of the high potential for harassment from urban activities and the opportunity this creates to begin evaluating the potential effects of harassment on salmon. Harassment affects the biological communities indicators.

B12: Harvest. Fish harvest can have a significant impact on a fish population's ability to persist over time. The combination of commercial, sport and tribal fisheries effectively reduces the number of adults returning to a stream system and can temporally segregate a population. For example, if overlapping harvest pressure is directed at the beginning of a return period, an unintended consequence is that fish from this earlier return period do not make it back to their natal stream, and life history traits may change or be lost completely (the population could move from an early run to a late run population, for example). The result is that the population as a whole becomes less resilient to environmental change. Although targeted sport fisheries are not necessarily allowed on lower Willamette fish populations (currently only hatchery populations are targeted), incidental harvest undoubtedly occurs. It is likely that harvest affects coho and Chinook populations the most.

B13: Hatchery Management. If not properly managed, hatchery programs can negatively affect Willamette fish populations in various ways. Smolts and fry released into areas where natural fish reside and rear can displace wild fish or compete for rearing grounds and food. Furthermore, smolts can prey directly on wild fish or attract predators, which results in higher prey rates on wild fish. In addition to impacts associated with hatchery releases, adult hatchery fish can return to native spawning grounds and compete for space, they may transmit disease, and if spawning is successful they can affect the genetic diversity of a wild population. Also, the abundance of hatchery returns can give the public a false sense that natural populations are healthy and thriving, when in fact the natural populations may be in peril.

However, benefits that can be realized from hatchery programs include supplementation (such as Umatilla steelhead supplementation programs) and reintroduction of native salmonids to rivers and streams in their historical range. If managed well, hatchery programs may be able to provide a benefit to fish populations.

B14: Spills and Illicit Discharges. Outfall discharges are typically permitted and managed through the National Pollutant Discharge Elimination System (NPDES) program under the Clean Water Act. However, spills and illicit discharges are unpermitted and often untreated discharges. Because these discharges typically occur accidentally, inadvertently or secretively, on purpose, it is difficult to apply best management practices or other treatments. Prevention, education and emergency response measures can reduce the potential for and impacts from spills and illicit discharges, but when they occur they have can have significant acute toxic effects. Spills and illicit discharges affect water quality and biological communities.

TABLE G-7
Indicators and Metrics of Human Influences

Indicators	Metrics
B1: Land Use	Percentage of industrial, commercial, residential, open space, etc. within watershed
B2: Impervious Surfaces	Total impervious area Effective impervious area *(begin to evaluate by tracking downspout disconnects, sumps and other types of disconnections and diversions)*
B3: Dam Impacts	Percentage and area of watershed above dams
B4: Water Withdrawals	Amount and percentage of water withdrawn
B5: Drainage Network	Percentage of piped/natural channel Number of miles piped/natural
B6: Channel Alterations	Culverts/stream crossings: number of stream miles currently accessible/miles historically available to fish; number, location and passablity of culverts and other stream crossings Bank hardening: percentage of “hardened bank” (riprap, seawall, bank with structures) Channel modification: channel sinuosity; number and area of instream structures; number and location of structures within the channel meander zone; number of pieces of large wood removed from stream

TABLE G-7
Indicators and Metrics of Human Influences

Indicators	Metrics
B7: Vegetation Management	Percentage of forest cover in watershed
B8: Wetland Alteration	Wetland area, location and quality
B9: Outfall Discharges	Location, pollutant loads and flows contributed by combined sewer overflows, stormwater and municipal and industrial outfalls
B10: Exotic Species	Number and percentage of exotic species (percentage by area for plants, by abundance for animals)
B11: Harassment (boat traffic, lights, noise, etc.)	Number of boats/day (large and small) Lumens of light with depth at night In-water decibels Number of people and pets/day
B12: Harvest	Incidental catch of wild (unmarked) fish in sport, commercial and tribal fisheries (Potential sources of this information are the Oregon Department of Fish and Wildlife and the Columbia River Inter-Tribal Fish Commission.)
B13: Hatchery Management	Number, location, size and time of hatchery smolts released in the Upper Willamette Basin, Clackamas River basin and lower Willamette River Number, location and time of unfed fry released into Portland watersheds Number of adult hatchery fish spawning in Portland waterways
B14: Spills and Illicit Discharges	Frequency, magnitude and toxicity of spills and illicit discharges

APPENDIX H

Technical Methods and Analytical Tools

APPENDIX H

Technical Methods and Analytical Tools

As the City of Portland follows the steps of the watershed management process presented in Chapter 3 of the *Framework,* it will use a variety of technical methods and analytical tools to assess current conditions in Portland's watersheds, rivers and streams; analyze and prioritize potential protection and restoration actions; and estimate the effects of those actions. The analogy of a toolbox is appropriate for describing the City's approach to using various technical methods and analytical tools. Given that each method or tool has a specific purpose or utility, and specific limitations, the entire "toolbox" will be needed to construct an understanding of watershed conditions, needs and actions.

The technical methods and analytical tools fall into three broad categories: empirical data collection, models, and management and decision-making tools. Each of these categories of tools is described in this appendix.

Analytical tools are not used directly to make decisions about watershed management, but they are useful in understanding and answering questions about watershed processes. No single analytical tool or method can be expected to answer all questions; analytical tools simplify and explain narrow portions of the broad and complex environmental system in the lower Willamette River. For this reason, the City's analytical "toolbox" contains a variety of analytical tools designed to address specific needs. These tools will be used in combination to inform watershed management decisions. In general, the City's approach emphasizes empirical data collection, as there is no substitute for actual data when assessing conditions and actions in Portland's watersheds, rivers and streams. Models are simplified representations; they have limitations and require assumptions that yield uncertainty, and often they cannot be tested. However, models are indispensable in evaluating current conditions that would be too costly or complex to measure adequately with empirical data. Models also are helpful in evaluating potential scenarios or conditions (such as future alternatives) for which data collection and testing are not possible.

Data collection, modeling, and decision-making tools will not in and of themselves yield decisions about the management of Portland's watersheds; rather, they will be used in combination with other information to understand watershed conditions and needed actions.

It is important to emphasize that the empirical data collection, modeling, and management and decision-making tools described in this appendix will not in and of themselves produce decisions with respect to resource conditions, needs and actions in Portland's watersheds, rivers and streams. They will, however, be used in combination with other information to inform such decisions.

Empirical Data Collection

The City of Portland regularly monitors a number of environmental indicators developed for use in characterizing the riverine-riparian ecosystem and determining the City's progress in achieving its watershed health goals. The City's monitoring program consists of several elements:

- A data gathering strategy, including scales and protocols
- Monitoring locations
- Monitoring parameters and methods
- Data quality assurance and quality control
- Data collection
- Data analysis and evaluation

The monitoring to be conducted for the watershed management process builds on existing monitoring programs that the City of Portland already is conducting as part of the management of its water, sewer, and other resources and facilities. In some cases, needed monitoring data will be obtained by revising or augmenting existing monitoring activities. In some instances, new, independent monitoring projects may be needed.

Types of monitoring that the City of Portland currently conducts are listed in Table H-1.

TABLE H-1
Examples of Types of Monitoring (by Purpose) Being Conducted by the City of Portland

Type of Monitoring	Type of Monitoring
Treatment processes (influent or effluent monitoring)	Discharge monitoring
Compliance monitoring (TMDL, NPDES, ESA, others)	Maintenance-generated sediment quality analysis (from stormwater facilities and sumps)
Spill identification and tracking	Groundwater level and quality analysis
Waterways sediment risk evaluation	Public health and safety—bacteria at contact use sites
Water quality and quantity facility monitoring	Physical systems characterization (stream geomorphology, flow characteristics)
Assessments of operation and maintenance practices for water quality effectiveness	Precipitation and other metadata
Mixing zone analysis	Pollutant source identification (chronic)
Ambient water quality evaluation	Flow monitoring (in-system and surface water)
Stormwater quality associated with facilities	

While a considerable amount of monitoring data have been and continues to be collected, significant gaps and variations remain in coverage across the City's watersheds. Because time and budget constraints generally prohibit the collection of the data needed to fill these gaps in the near term, proposed analyses have been designed to capitalize on the strengths and balance the weaknesses of existing data and programs. The availability and adequacy of existing data and information will determine the extent to which the critical questions can be addressed during watershed characterization (see Steps 3 and 4 in Chapter 3). In some cases, the unevenness in the depth and breadth of the available data will limit what watershed health questions can be answered. In general, though, the data are sufficient to provide at least general direction to watershed planning. In many cases the data are adequate to support very specific recommendations.

Fisheries Studies

The *Framework* currently places an emphasis on hydrology, water quality and aquatic/riparian habitats, notably because of the importance of these watershed processes and features to fish species listed under the Endangered Species Act (ESA). Thus fisheries studies conducted by the City are particularly important as technical tools for use in helping to analyze the conditions and needs of the City's watersheds and waterways.

In 1998, the City Council resolved to assist in the recovery of ESA-listed species in Portland. Beak Consultants was retained to assess the potential for various City activities to affect the Lower Columbia River evolutionarily significant unit (ESU) of steelhead that recently had been listed as threatened under the ESA. Beak Consultants compiled information to define City activities that have the potential to affect steelhead, determined pathways by which effects might occur and identified options and next steps for planning and implementing ESA conservation planning and compliance.

Beginning in 1998, the City contracted with the Oregon Department of Fish and Wildlife (ODFW) to conduct a four-year fish evaluation study along the banks of the Willamette River. The intent of this study was to evaluate the relationship between fish in the lower Willamette River and bank treatments and near-shore conditions. The study was conducted year-round, such that seasonal distributions and patterns of use could be evaluated. In addition, migration travel time and salmonid consumption by predators was evaluated as part of the study.

In addition to the mainstem Willamette fish study, a complementary tributary study was conducted from July 2001 through June 2003. This study was designed to evaluate fish presence and absence, seasonal distribution and biotic integrity of fish populations in key tributaries to the lower Willamette River. Watersheds evaluated included Johnson Creek (including Crystal Springs), Tryon Creek, Stephens Creek, Miller Creek, Saltzman Creek, Doanne Creek and Balch Creek.

The City continues to conduct seasonal fish presence and absence surveys in key tributary reaches. Studies are conducted quarterly to evaluate seasonal presence and are designed to document fish presence in reaches where proposed stream restoration and fish improvement projects have been identified. This will allow the City to monitor the success of these projects.

In addition to these fish surveys, the City conducts a modified rapid bioassessment survey that is consistent with the U.S. Environmental Protection Agency's (EPA) environmental monitoring. To date, these surveys have been conducted in the Tryon and Johnson Creek watersheds. Types of data collected to evaluate watershed conditions include percent fines overlaying stream bottom substrate, evidence of bank erosion, dominant habitat type, presence of large wood and large substrate, maximum pool depth, composition and size of riparian vegetation, and percent tree canopy closure. These surveys are conducted once annually per monitoring site.

The City evaluates U.S. Geological Survey (USGS) flow data and stream temperature data seasonally. These data are measured continuously at the USGS flow gauges in several of Portland's watersheds. The City evaluates these data to determine seasonal patterns in flow and temperature, to evaluate compliance with temperature standards and to assess the degree of hydrologic alteration through evaluation of the indicators of hydrologic alteration described in Appendix G and other aspects of watershed characterization.

The City relies on other empirical studies conducted by state and local governments, municipalities and institutions and other interest groups to augment instream data collected by the City. For example, from 1999 through 2001, ODFW conducted fish surveys in Fanno Creek (including areas in the larger Tualatin River basin). Data from these surveys have been invaluable in evaluating fish presence and distribution in Fanno Creek basin. Key entities that conduct empirical studies include the following:

- Johnson Creek Watershed Council
- Friends of Tryon Creek
- Ducks Unlimited
- ODFW
- Metro
- Multnomah County

In addition to collecting biological community and instream habitat survey data, the City has conducted numerous studies and developed comprehensive reports that characterize hydrology, water quality, riparian ecology and wildlife in lower Willamette basin tributaries, mainstem reaches and the Columbia Slough. These comprehensive characterizations evaluate the indicators described in Appendix G and other factors relevant to watershed planning.

Modeling

The City has a number of modeling tools available to assist in technical analyses of the conditions and needs of the City's watersheds and waterways. These models vary in scope and complexity, and their application will vary depending on the analytical needs or problems in particular watersheds. In evaluating potential models to use, the following questions are considered:

- Is the model needed for the analysis (perhaps in lieu of or in addition to empirical data)? If so, is the model appropriate for the purpose of the analysis?
- To what extent will the model be able to extend the City's knowledge and ability to address critical questions using existing data?
- How understandable is the model and its results?
- What are the model's strengths and limitations relative to the problems for which it will be applied?
- How can the model's uncertainty be reduced?
- Can the model be used in combination with other models or data collection to more completely address questions and reduce uncertainty?
- Can the model be implemented within current time and budget constraints?
- Will the time, expense, and data necessary to operate the model result in commensurately better planning decisions?

The appropriate use of models will be further defined in consultation with stakeholders and technical experts during the alternatives development process. The models used, the level of confidence associated with their use and the basis for decisions about priority actions will be documented. Similarly, policy makers will be well informed about the limitations of the models selected.

Three key modeling tools are described in this section:

- Ecosystem Diagnosis and Treatment, or EDT. The EDT model has been selected by the Northwest Power and Conservation Council for subbasin planning work across the region and has been used extensively in Puget Sound, including in the urban systems in the Seattle-Tacoma area. The model forecasts the response of fish and wildlife populations[1] to specific habitat conditions and is made up of a detailed database of stream habitat characteristics and species-specific algorithms that have been peer-reviewed by leading Pacific Northwest scientists. EDT is used to identify key environmental problems, determine protection and restoration priorities and evaluate the effectiveness of watershed restoration alternatives in meeting objectives for habitat conditions and fish and wildlife populations.
- Integrated Hydrologic and Water Quality System Modeling. Hydrologic and water quality models provide tools for the analysis, planning and management of a wide range of water resources and environmental problems related to surface water and groundwater, in particular when the effect of human interference is to be assessed. These models simulate flow and the transport of dissolved contaminants and sediments in both surface water and groundwater. Areas of application include water use, water resources management, wetland protection, surface and groundwater interaction and contaminant transport. The results of analyses from these models can be used as inputs to EDT to determine whether actions aimed at hydrology or water quality improvements meet City objectives.
- Habitat Equivalency Analysis (HEA) and Net Environmental Benefit Analysis (NEBA). The HEA model was developed by the U.S. Department of the Interior and has been used extensively by the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service (USFWS) and numerous state resource agencies. The HEA model uses output from EDT and other information to calculate the amount of ecological benefit that is expected to result from a particular restoration action over time. HEA takes into consideration how well a restoration action will perform over the long term—whether its benefits will be maintained at a steady level, increase or decrease (and if so, at what rate). In addition, HEA expresses the ecological benefits of various restoration actions using a common unit of measure, making the model useful in comparing the long-term benefits of different potential actions.

  NEBA combines output from HEA concerning future ecological benefits with the costs of various restoration actions. By calculating a cost-per-unit-of-benefit value for each restoration action being considered, NEBA identifies those watershed activities that offer the greatest potential benefit for the amount of money spent.

Each model reflects current scientific understanding, has been applied in a number of other venues and complements the capabilities of the other models. Together they provide a suite of models for identifying the most effective approaches to restoring urban watersheds and evaluating how well those approaches will meet stated objectives for watershed health.

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[1] EDT is currently focused on evaluation of salmon and steelhead populations but is being developed further to evaluate a broad range of fish and wildlife species.

Combined with the use of empirical data, these modeling tools will assist the City in characterizing existing conditions and constraints in a watershed; this characterization then can be used to develop solutions to address specific habitat limitations and problems. The modeling, combined with empirical data, allows the development of a scientifically grounded understanding of the causes of environmental changes and declines in water quality and species such as salmon.

EDT

EDT is an analytical tool that relates habitat features and biological performance to fish survival and productivity. The model captures a wide range of environmental information, making it accessible to planners, decision makers and scientists in a form that explains the underlying mechanisms of the ecosystem. EDT acts as an analytical framework that brings together information from empirical observation, local experts and other models and analysis.

What is EDT?

EDT, or Ecosystem Diagnosis and Treatment, is an analytical tool for rating the quality and quantity of habitat with respect to one or more focal species.

EDT uses salmon as a "probe," or indicator, to identify the most significant problems in a watershed and the priority stream or river reaches for protection and restoration.

EDT can best be described as a scientific model. It differs from many models used in fish and wildlife conservation in that it is habitat based and attempts to explain and model the mechanisms behind phenomena. This contrasts with more conventional statistical models, which typically focus on fish population dynamics and provide correlation-based predictions of events without necessarily explaining the underlying mechanisms.

EDT constructs a model of a subbasin as a basis for planning and for use in comparing alternative future scenarios. The EDT model is based on the premise that habitat shapes biological performance of a salmon population and that individual habitat attributes can be related to fish performance, based on existing scientific knowledge. EDT provides measurable metrics to gauge progress. The model relates habitat characteristics to salmon population performance in terms that can be related to recovery standards for fish populations listed under the Endangered Species Act. EDT also is useful in planning effective recovery strategies because it contributes to the understanding of the complexity of ecological systems and how habitat change affects fish populations.

Although EDT is a salmon habitat model, it has implications beyond salmon. The City uses salmon as a biological "probe" of the aquatic environment in the belief that an environment that supports productive populations of native fish species has desirable characteristics that are consistent with the needs of other native fish and wildlife species. By using salmon as a key biological indicator, the City can draw on the rich scientific literature related to salmon and evaluate actions relative to species that have important social value and legal implications.

Unlike statistical models, which seek to reduce complexity to a small number of predictive or correlated variables, EDT helps describe the complexity of ecological systems.

The underlying premise of EDT is consistent with the *Framework*'s salmonid ecology principles, which explain that the persistence, abundance, diversity and productivity of species such as salmon are a reflection of the habitat conditions those species experience over the course of their life histories. For a species to recover, it must have the appropriate quantity, quality, location and connectivity of habitat at each stage in its life history. For aquatic species, habitat conditions are a function of conditions throughout the watershed, which in urban settings is influenced heavily by human actions. In Portland, stream conditions and associated species are likely to be affected by the area's continual development, and restoration and management of aquatic habitat in urban areas will likely require redirection and modification of actions that constrain habitat conditions. Because Portland is an urban setting, successful watershed restoration will require not only an understanding of the biological basis for restoration, but also the incorporation of engineering, social and economic aspects.

How EDT Works

EDT has two major components:

- **A detailed description of the habitat.** EDT describes habitat using 45 biologically significant attributes that relate to specific aspects of habitat for each month of the year for each stream reach.[2] These attributes reflect the environmental indicators described in Appendix G.
- **A set of rules that describe how a species responds to that habitat.** The rules describe the focal species' response to environmental conditions in terms of life stage productivity and capacity. By integrating a species' response to environmental conditions over the species' life history, EDT provides information on population abundance, productivity and diversity.

Taken together, the environmental attributes and rules in EDT provide, respectively, monitoring attributes and research hypotheses that can serve as the foundation for accountability, monitoring and research. These environmental attributes and rules can be developed and tested using a variety of statistical methods and research. In this way, EDT provides a scientific basis for natural resources planning and action.

During the characterization stage of the watershed management process (Steps 3 and 4), EDT is used to diagnose problems and constraints in the watershed relative to the needs of species such as coho salmon. In other words, terms such as "good," "bad," "healthy" or "unhealthy" are defined with respect to the biological needs of the species.

It is important to emphasize that the environmental attributes EDT uses to describe and evaluate habitat have a strong relationship to the watershed health indicators described in Appendix G. The connections between EDT attributes and *Framework* indicators are shown in Table H-2.

The diagnosis begins with a characterization of the current habitat conditions. EDT brings together information regarding the current condition and actual quantity of habitat and provides a forum for documenting existing knowledge, including the quality and reliability of that knowledge. A second characterization is also developed, to provide a standard against which to compare current conditions. This second characterization is of "reference" habitat conditions that could reflect various reference states, such as historical conditions or the

[2] A stream reach is a distinct portion of a stream defined by valley form, land use or other criteria, such as tributary confluences.

habitat's ecological potential, meaning the conditions that would exist if all habitat attributes were functioning properly.

EDT then compares current conditions to the reference conditions for each stream reach in order to assess the quality and quantity of habitat for the focal species at different life history stages as a function of habitat in that reach. Constraints, habitat changes and restoration opportunities are identified. Planners then have a blueprint that identifies problems that need to be addressed in a watershed and the features or ecological functions that need to be preserved, enhanced or restored.

TABLE H-2
Connections Between EDT Attributes and the *Framework* Indicators

EDT Attributes		Corresponding *Framework* Indicators
Change in interannual variability in high flows, changes in interannual variability in low flows, intra-annual flow pattern and intradaily flow variation	Watershed Hydrology	Hydrograph alteration
Channel confinement		Floodplain quality and connectivity
Riparian function	Physical Habitat	Riparian condition: width, composition and fragmentation
Fine sediment, embeddedness, small cobble/riffle habitat type		Channel substrate (fine/coarse)
Primary pools, backwater pools and pool tailouts (for tributaries); area of shallow water (< 20 ft) (for large rivers)		Refugia
Off-channel habitat		Off-channel habitat
Wood		Large wood
Temperature/daily maximum; temperature/spatial variation	Water Quality	Water temperature
Dissolved oxygen		Dissolved oxygen
Nutrient enrichment		Nutrients and chlorophyll *a*
Turbidity		Total suspended solids
Metals in water column, metals/pollutants in sediment/soils, miscellaneous pollutants in water column		Toxic contamination of water sediments and biota, 303(d)-listed parameters, other parameters (as determined by the weight of evidence)
Benthos diversity and production, fish community richness	Biological Communities	Biotic integrity, benthic macroinvertebrates, salmonid population structure
Fish species introductions, hatchery fish outplants, predation risk		Species interactions (predation, competition, etc.), exotic species
Water withdrawals	Human Activities	Water withdrawals
Hydromodifications, channel length, obstructions to fish migration		Channel alterations
Harassment (boat traffic, lights, noise, etc.)		Harassment

Integrated Hydrologic and Water Quality System Modeling

MIKESHE and other hydrologic and water quality models complement the capabilities of EDT. Using the output from EDT, the hydrologic and water quality models aid the development of effective restoration approaches in the following ways:

- By identifying and quantifying sources of degradation (see Restoration Guideline 3.3)
- By predicting the effectiveness of protection and restoration actions in addressing these sources
- By evaluating the degree to which a set of restoration actions will achieve protection and restoration objectives

> **Integrated Hydrologic and Water Quality System Modeling**
>
> The City of Portland uses a variety of modeling tools to simulate and predict the hydraulic and transport behavior of the City's combined, sanitary, stormwater and natural drainage systems:
>
> - EPA's SWMM, PDX SWMM, XP SWMM
> - HEC-1, HEC-RAS
> - DHI's MIKESHE
>
> These hydrologic and water quality models complement EDT by identifying and quantifying sources of degradation and evaluating the effectiveness of potential restoration actions.

Historically the City of Portland has used a variety of modeling tools, including EPA's SWMM, PDX SWMM, XP SWMM, HEC-1 and HEC-RAS and the Danish Hydraulic Institute's (DHI) Mouse, to simulate and predict the hydraulic and transport behavior of the City's combined, sanitary, stormwater and natural drainage systems. More recently, the City of Portland has implemented DHI's state-of-the-art MIKESHE system, an integrated set of hydraulic, hydrologic and water quality modeling tools. MIKESHE is used to simulate flow and the transport of solutes and sediments in both surface water and groundwater. Areas of application include water use, water resources management, wetland protection, surface and groundwater interaction and contaminant transport.

MIKESHE is a physically based model, meaning that it uses computer simulation to portray the actual physical conditions and processes affecting flow and the transport of solutes and sediments in the watershed. Because the MIKESHE modeling software has a modular structure, individual components can be used independently and customized to specific needs, depending on the availability of data and the aims of the given study. The flow processes represented in MIKESHE include rainfall interception and evapotranspiration, overland flow and channel flow, and snowmelt and groundwater flow. Each of these processes operates in the model at its own spatial and time scale.

For example, daily rainfall might be distributed into a few zones across a watershed, because of topographic relief. Infiltration and evapotranspiration will vary with vegetation, surface cover, slope and soil properties and are automatically calculated and distributed in the model, based on the values for such parameters. Stream and river flows typically show the quickest response to rainfall events, whereas groundwater typically shows the slowest. In areas with shallow groundwater that is in full contact with local surface water, the model provides a dynamic description of the interaction between surface water and groundwater at daily or even hourly intervals. This is of particular importance to the City of Portland in understanding stormwater runoff behavior and response during storm events.

The MIKESHE model or other hydrologic models can also be used to help test specific proposed solutions. For example, if characterization reveals that high stream flows have scoured gravels and reduced the spawning success of Chinook salmon, the MIKESHE model can be used to help assess how watershed features and activities, such as impervious areas or stormwater system modifications, affect flow runoff quantities delivered to and routed through the stream. Planners and analysts can work back and forth to explore the feasibility and contribution of different actions. The result is a management alternative that contains a prioritized set of actions that address identified environmental problems and that are based on explicit scientific knowledge.

Similarly, a proposal to develop a subdivision near a creek can be evaluated as to the expected increase in effective impervious surfaces and the impact of this increase on surface flow, groundwater and pollutant inputs. These changes in the physical environment can then be entered into EDT to examine their potential impact on the habitat and performance of the species of interest.

Habitat Equivalency Analysis (HEA)

The HEA model was originally developed by the U.S. Department of the Interior and has been used extensively by NOAA, USFWS and numerous state resource agencies. The model has been useful in natural resource damage assessment cases (both in Comprehensive Environmental Response, Compensation and Liability Act [CERCLA] and Oil Pollution Act regulatory cases) to determine restoration actions required to address levels of damage (referred to as "injury") to natural resources from contaminants and pollution spills.

The HEA model focuses on the amount of ecological services performed by a natural resource, such as a particular habitat, over time. "Ecological services" refers to the functions that a natural resource provides to benefit the environment and human uses. A sample resource would be a wetland, which typically provides ecological services such as sediment stabilization, water quality improvements (as a result of natural filtration), storm protection, nesting areas and materials for birds and—for both fish and birds—forage and refuge from predators. Other services a wetland might provide include opportunities for commercial or recreational fishing, bird watching and hunting.

What is HEA?

Habitat Equivalency Analysis (HEA) can use output from EDT and other sources to calculate the amount of ecological benefit that is expected to result from a particular restoration action over time. HEA takes into consideration how well a restoration action will perform over the long term—whether its benefits will be maintained at a steady level, increase or decrease (and if so, at what rate). In addition, HEA expresses the ecological benefits of various restoration actions using a common unit of measure, making the model useful in comparing the long-term benefits of different potential actions.

What is NEBA?

Net Environmental Benefit Analysis (NEBA) combines output from HEA concerning future ecological benefits with the costs of various restoration actions. By calculating a cost-per-unit-of-benefit value for each restoration action being considered, NEBA identifies those watershed activities that offer the greatest potential benefit for the amount of money spent.

HEA can use out put from EDT and other information to calculate how much the ecological services performed by a particular habitat will change over the long term as the result of a particular restoration or protection project. The model considers such factors as the size of the project area, the time it will take for the restoration project to "mature" to the point that it provides its full level of ecological service, how much of an increase that full level of ecological service represents, how long the full level of service will last and, if there is an increase or decrease in the level of service over time, whether that increase or decrease will be gradual or precipitous.

Because HEA calculates the long-term ecological benefits that will accrue from each potential action and expresses those benefits using a common unit of measure (typically discounted service-acre-years, or dSAYs), the model is useful when comparing the respective merits of various restoration actions being considered for implementation.

Net Environmental Benefit Analysis (NEBA)

The output of the HEA model is a statement of the respective ecological benefits that will result from various potential restoration actions. A net environmental benefits analysis takes this information and pairs it with the costs of developing and implementing each restoration action, to identify those actions that offer the greatest ecological benefit for the amount of money spent. Put simply, because the future ecological benefit and cost of each potential project are known, NEBA can calculate the cost per unit of benefit for each restoration action being considered. This information has obvious applications when selecting among different restoration options.

To ensure accurate comparisons of restoration actions that have widely different time frames, a HEA/NEBA analysis back-calculates future costs and ecological benefits into today's dollars. This accounts for the changing value of money over time.

Used together, the HEA model and a NEBA entail the following steps:

- Quantifying the ecological services, or benefits, that will be provided by potential restoration projects, using the HEA model with input from EDT, MIKESHE and other tools
- Identifying the costs of developing and implementing the potential projects
- For each project, calculating the cost per unit of ecological benefit or, conversely, the level of benefit that will be provided for each dollar of cost

The net environmental benefit analysis is simply a comparison of (1) the ecological gains or losses associated with each management alternative, and (2) the costs associated with each action.

The end product is a balance sheet that provides a comparison of which options or activities offer the greatest net environmental benefit per project cost when compared to the other options.

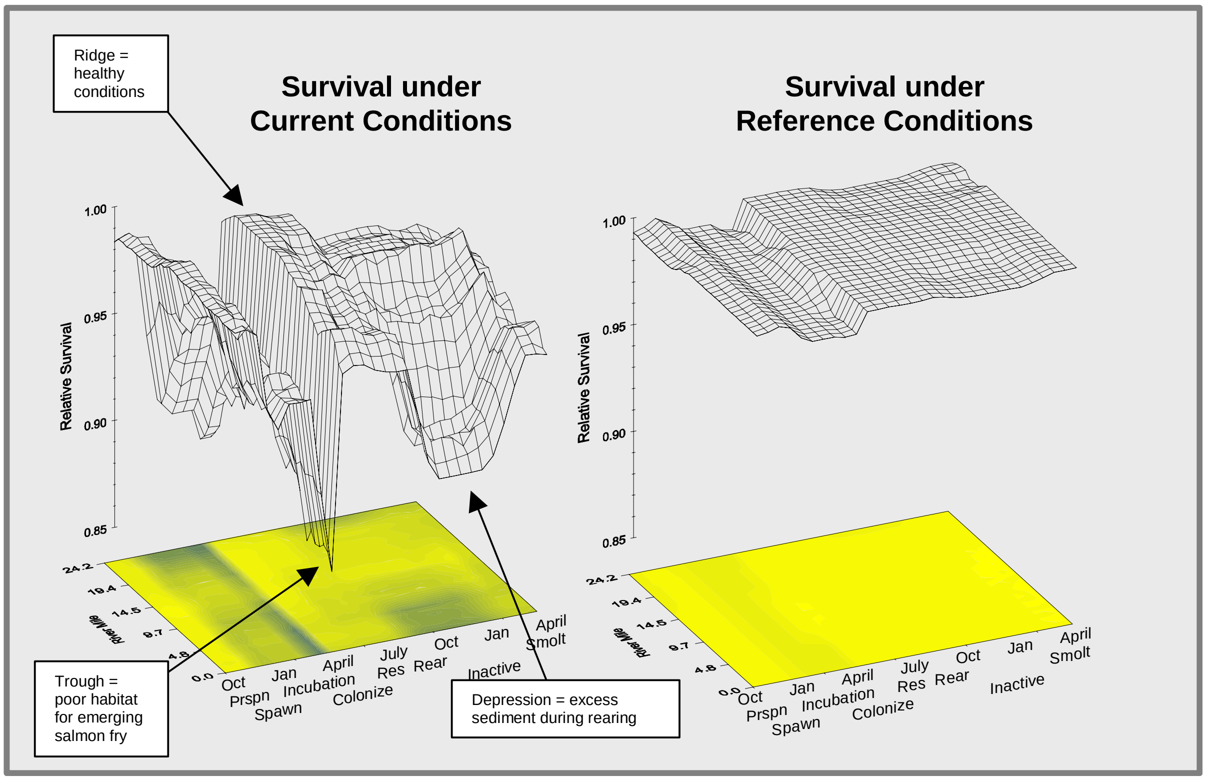
If desired, a NEBA can also include a quantification of the human use value, such as commercial fishing or bird watching, associated with a particular management action.

Examples of Output from the City's Modeling Tools

The models provide a variety of types of outputs that can be useful in developing and evaluating potential watershed management actions. Some of these are discussed below.

Output Useful in Pinpointing Habitat Problems and Opportunities. The City uses output from EDT to compare the current habitat conditions in a watershed to reference conditions, which usually reflect historical conditions or conditions that would exist if all environmental attributes in a stream reach were functioning properly. Figure H-1 is a sample comparison of two "survival landscapes" for a particular stream. It shows survival rates of a salmon population by location and through time under current conditions and reference conditions. Pits and valleys in the landscapes are times and places within the watershed where salmon survival declines as a result of habitat conditions. High points or peaks indicate higher survival rates.

FIGURE H-1
Sample Comparison of Salmon Survival Under Existing Conditions in a Stream and Under Reference Conditions



The figure shows that, under current conditions, there is a deep "trough" in the landscape during the spring months along the entire 24-mile length of the river being modeled. This trough indicates a time-sensitive environmental problem—in this case, a lack of adequate habitat complexity when salmonid fry are emerging from gravel in the spring. The figure also indicates an additional problem, represented by the depression during the winter months in the first few river miles. This depression corresponds to excess accumulation of fine sediment in the streambed during the spawning period. Another key feature of this particular survival landscape is the somewhat high "ridge" running next to the deep trough, during late spring and early summer, particularly in the upper river miles. This indicates a watershed asset, meaning properly functioning watershed conditions that, if maintained, are likely to help sustain important species and habitats.

Output Useful in Prioritizing Actions. By comparing survival under current and reference conditions, as in Figure H-1, areas where change is greatest and thus restoration is most needed become clear. Likewise, areas where change is the least might indicate opportunities for protection.

It is also useful to compare the difference between current conditions and potential future degraded conditions. This is the "preservation" value of the habitat, meaning the value of the current habitat if it is prevented from being further degraded from the existing state. Likewise, the difference between current conditions and potential future restored conditions is the "restoration" value of the habitat, meaning the value of the habitat if it is restored from the existing state to the habitat's assumed full potential. Figure H-2 represents these differences schematically.

FIGURE H-2
Schematic Representation of Preservation and Restoration Values

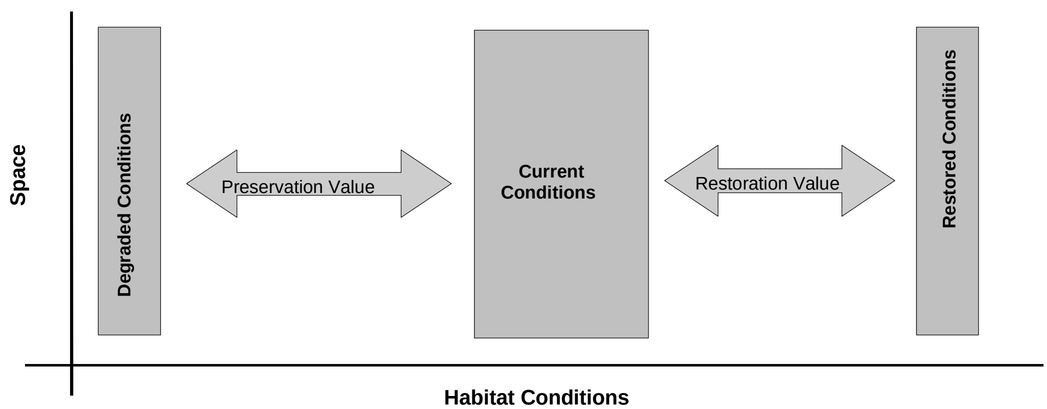
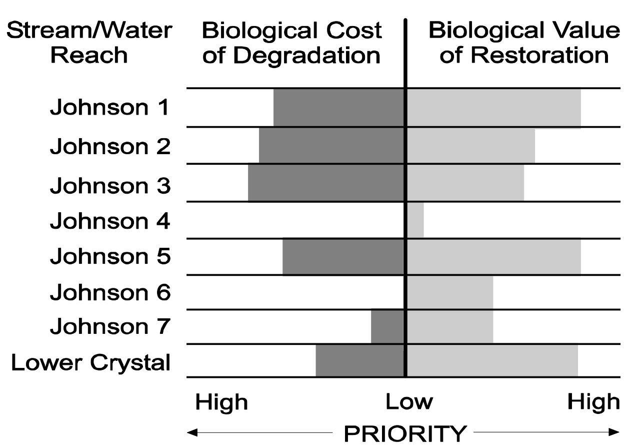


Figure H-3 shows how preservation and restoration values can be tied to specific stream locations. In Figure H-3, the biological costs of degradation and the value of restoration suggest how restoration or preservation activities in various stream reaches might be prioritized.

FIGURE H-3
Preservation and Restoration Values for Johnson Creek Stream Reaches (for Fall Chinook)



Output Useful in Identifying Factors That Affect Survival and Capacity of Focal Species. The City uses output from EDT to assess the quality and quantity of habitat in a watershed relative to the biological requirements of a fish species, such as Chinook salmon. In each of their life stages, Chinook have unique habitat needs that must be met if the species is to persist and thrive. In the characterization stage of the watershed management process, habitat conditions are identified and compared to the needs of each life stage. This information can be summarized in a chart like the one in Figure H-4, which shows how various habitat characteristics, such as flow, channel stability and water quality, affect the survival and capacity of Chinook salmon life stages in each reach of a creek. The sizes of the circles represent the amount of change that has occurred relative to reference conditions. By looking at each reach of the stream in this manner, areas and types of change are highlighted and priorities for restoration actions can be identified.

Output Useful in Performing Economic Analyses (HEA/NEBA). Economic analyses will play a role in the watershed management process, as a way to compare the costs and benefits of potential restoration actions and possibly to aid in a natural resources damage assessment under CERCLA. The primary tools the City will use for these are HEA and NEBA.

As described earlier in this appendix, the HEA model expresses the ecological benefits of different courses of action in a common unit—typically the service-acre year, or SAY[3]—so that the long-term benefits of different potential actions can be compared. Figure H-5 diagrams a sample of such a comparison of two alternate restoration scenarios theoretically being considered for a particular location. Scenario A involves tree planting and reductions in the amount of impervious surfaces. Scenario B involves erosion controls and development rules. For both scenarios, the wedge above the baseline services line represents the ecological services that would result if the actions were implemented.

FIGURE H-4
Factors Affecting the Survival and Capacity of Coho in a Sample Reach of Johnson Creek

Life stage	Relevant months	% of life history trajectories affected	Productivity change (%)	Life Stage Rank	Change in attribute impact on survival: Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Spawning	Oct-Jan	0.6%	-29.2%	6					High		Extreme	High					High			Moderate
Egg incubation	Oct-May	0.6%	-77.9%	1	High				High			Moderate					Extreme	Moderate		Moderate
Fry colonization	Mar-May	0.6%	-30.2%	5	High			Moderate	High	High	Extreme						High			Extreme
0-age active rearing	Mar-Oct	0.4%	-68.2%	2	High		High	Moderate	High	High	Extreme	Moderate		Moderate	Moderate	Moderate	Small	Moderate		High
0-age migrant	Oct-Nov	0.4%	-12.8%	8							High						Moderate			Moderate
0,1-age inactive	Oct-Mar	0.3%	-88.4%	3	High				Extreme	High	Extreme						High	Small		High
1-age migrant	Mar-Jun	0.3%	-0.2%	9							Moderate									Moderate
1-age resident rearing	Mar-May	0.3%	-37.5%	7	Moderate		Moderate	Moderate	High	High	High	Moderate					Small			High
1-age transient rearing																				
2+-age transient rearing																				
Prespawning migrant	Sep-Nov	0.6%	-0.1%	10							Small	Small								Moderate
Prespawning holding	Oct-Dec	0.6%	-32.4%	4					High		Extreme	High					High			Moderate
All Stages Combined		1%																		

1/ Ranking based on effect over entire geographic area. 2/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.
Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

KEY

NA = Not applicable

	Loss	Gain
None		
Small	● (small filled)	○ (small open)
Moderate	● (moderate filled)	○ (moderate open)
High	● (high filled)	○ (high open)
Extreme	● (extreme filled)	○ (extreme open)

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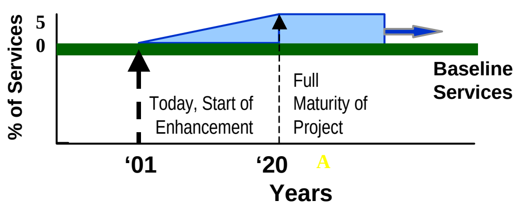
[3] A service-acre year is the area (in acres) of usable and suitable habitat that is available over a year's time.

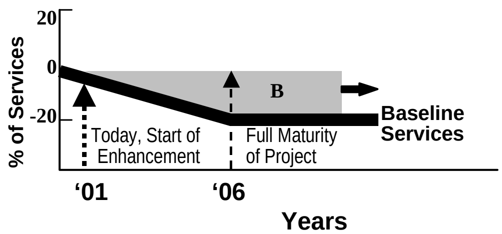
FIGURE H-5
Sample HEA Comparison of Two Hypothetical Scenarios

Scenario A: Tree Planting/Impervious Surface Reductions



Water quality and salmonid benefits = 60.2 SAYs
Recreation/fishing benefits = $120,326

Scenario B: Erosion Control/Development Rules



Water quality and salmonid benefits = 2,499 SAYS
Recreation/fishing benefits = $1,249,489

Note: SAY = service-acre years

Under Scenario A, the full benefit of the tree planting and impervious surface reductions would first be realized in the year 2020. Over the 50-year life span of the project, water quality and salmonid benefits would amount to 60.2 SAYs and recreation and fishing benefits would provide $120,326 in public fishing and recreational value.

This compares to water quality and salmonid benefits of 2,499 SAYs under Scenario B, which involves erosion control and development rules that would prevent further degradation. Under this scenario, full benefits would first be realized in 2006, offering $1.2 million in public fishing and recreational value over the 50-year lifespan of the project.

Table H-3 shows the net environmental benefits analysis for the two scenarios, using the project cost and HEA-calculated ecological value in SAYs to compute a dollar cost per unit of value generated under each scenario. The NEBA indicates that Scenario B would result in greater ecological benefit overall at a lower per-unit rate ($0.32 per unit compared to $2.08 per unit).

An important aspect of the HEA/NEBA analysis is the ability to assess the accrual of ecological value generated by actions over time. Thus the analysis takes into account the ecological value of an action not only today but as it will accrue into the future. The analysis also can demonstrate both the ecological and monetary value of implementing certain actions sooner rather than later.

TABLE H-3
Net Environmental Benefits Analysis Comparing Benefits and Costs under Two Hypothetical Scenarios

Alternative	HEA Ecological Value Generated	Cost	$/eco	Public Use Value Generated	$/pv
Scenario A: Riparian Buffer/ Impervious Surface	60.2 SAYs	$250,000	$4,152	$120,326	$2.08
Scenario B: Erosion Control/ Development Rules	2,499 SAYs	$400,000	$160	$1,249,489	$0.32

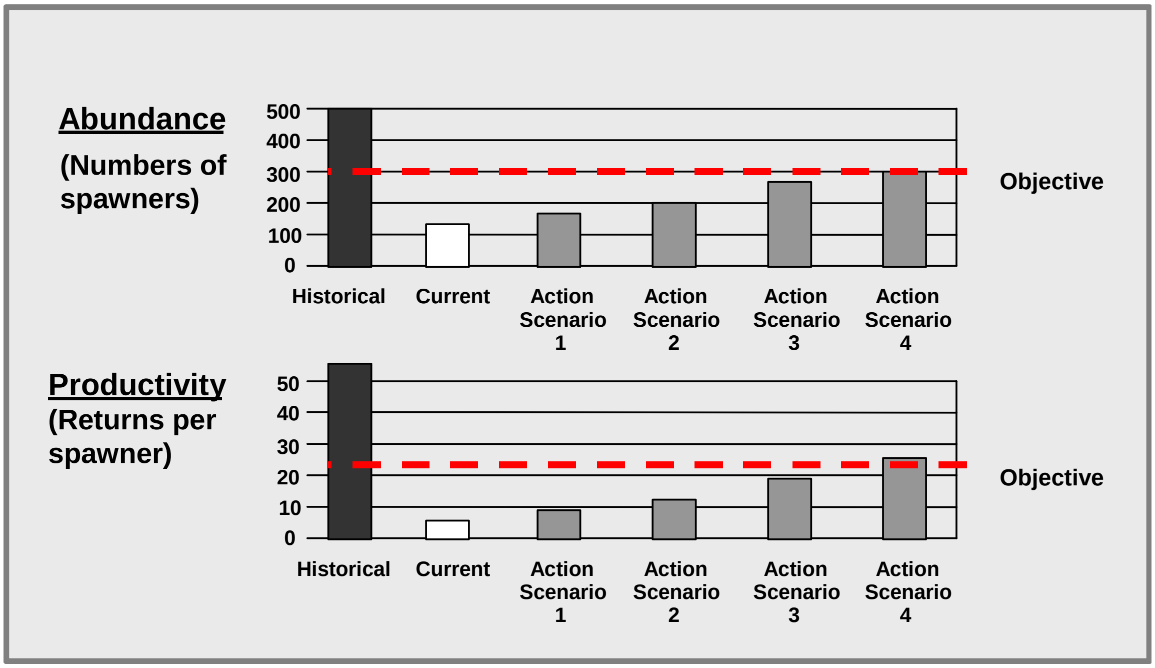
HEA = habitat equivalency analysis
SAY = service acre-year
$/eco = cost per ecological credit
$/pv = cost per $ of value generated

Integrating Components of the Models

The various models can be integrated as needed to characterize current watershed conditions and assess the effects of different management actions on watershed processes and habitat attributes. For example, as a preliminary step, geographic information system (GIS) spatial analysis could be used to manage data and produce maps that depict current conditions and conditions that would occur under various action scenarios. Mathematical models such as MIKESHE could then be used to estimate hydrology and water quality conditions at various locations and reaches within the watershed. (These models are useful in helping policy makers understand the relative magnitude of potential changes in conditions that are likely to result from different action scenarios. Similarly, the use of models helps ensure thorough documentation of the assumptions used in evaluating different management options and in facilitating discussions among stakeholders and technical experts.) EDT would then be run for several scenarios, to compare graphically the predicted effects on fish abundance, productivity and diversity (see Figure H-6). This analysis provides information valuable in the prioritization and selection of a preferred set of actions.

In addition to comparing different alternative sets of actions, this same approach can be used to track the progressive effectiveness of a preferred set of actions over time. This allows for evaluation of when a benchmark or objective will be achieved.

FIGURE H-6
Graphical Comparison of Potential Action Scenarios



An Additional Analytical Tool: Spatial Analysis Using GIS

An additional analytical tool the City is likely to use is GIS for spatial analysis of data related to watershed data. Currently the City maintains a wide range of data on natural features, infrastructure, zoning, development and other components that support the planning, development, maintenance and management of City functions. This includes natural resource data (information on soils, vegetation cover, water features, topography, watersheds, floodplains, wetlands, etc.) and regularly updated information on the built environment (streets, tax lots, transit, population, land use, stormwater drainage, water mains and sewer lines, building footprints and public places such as schools and parks). These data are stored and organized using GIS software and can be analyzed spatially in support of the watershed management process presented in Chapter 3.

The multiple bureaus within the City of Portland regularly share GIS data. This allows the bureau most closely tied to each type of information to maintain the data and provide the most current information to the other bureaus. For example, information on street features is tracked by the Portland Department of Transportation, while information on building permits and land use reviews is maintained by the Bureau of Development Services. Water main data are the province of the Bureau of Water Works, and the Bureau of Environmental Services (BES) is responsible for sewer line and stormwater drainage data. Most of the bureaus use various types of Environmental Systems Research Institute (ESRI) brand GIS software, such as ArcView 3.x and 8.1, ArcInfo 8.1 and MapObjects. BES currently uses MapInfo but can regularly share data with other GIS platforms with little difficulty. The City also shares data with Metro, the area's regional government. Metro provides broader regional coverage of GIS data, while the City maintains more detailed data on conditions within Portland. The coordination and data sharing between the two entities provide for stronger data sets and greater cost effectiveness.

The City uses GIS to display data on maps (or "coverages") of various resources and land features. The high quality and extensive body of spatial data available for watershed management will support sophisticated analyses of environmental conditions and link conditions to human actions throughout the watershed. The resolution and quality of data will be important in mapping the locations of environmental problems, identifying the potential pathways contributing to the problems, quantifying sources and developing solutions.

Management and Decision-Making Tools

The City also has the option of using multi-attribute analysis software and environmental management systems to evaluate potential restoration and protection actions and manage the planning activities, staff responsibilities, practices and resources needed to implement selected actions on an ongoing basis. These tools are described below.

Multi-Attribute Analysis Software

When selecting a preferred alternative, it may be helpful to use methodologies or software packages specifically designed to conduct a multi-attribute analysis of different alternatives. Such an analysis provides a systematic means of applying and tracking the rating of alternatives based on various evaluation factors and criteria. The analysis also generates a total score for each alternative, with the score reflecting the degree to which that alternative is likely to achieve the City of Portland's identified values, taken as a whole. The total score is simply the sum of scores derived for each evaluation factor, in which the score for each factor is determined by multiplying the value given each factor (based on quantitative or qualitative criteria) times the factor's established weighting.

Two types of outputs are likely to be particularly useful when reviewing the results of a multi-attribute analysis:

- **Benefit contributions by component values.** This provides information about which value, or evaluation factor, most influences an alternative's relative ranking, either high or low. Essentially, this output explains why a particular alternative is ranked as it is. As a simplified example, consider a hypothetical situation in which two alternatives are being proposed in a watershed area to reduce erosion and sediment loading to protect existing areas of high-quality habitat. Alternative A includes actions to change zoning to prevent streamside construction that contributes to erosion and sediment loading. Alternative B includes actions to revegetate streamside riparian areas to prevent channel bank erosion that contributes to erosion and sediment loading. The multi-attribute analysis reveals that the total score for both alternatives is the same. However, an examination of the contribution to the score by evaluation factor indicates that Alternative A is rated higher than Alternative B for technical effectiveness in actually reducing soil material that contributes to erosion and sediment loading, but is rated lower than Alternative B in overall costs of implementation and maintenance.
- **Weighting sensitivity analysis.** This shows how much the weighting of a particular value could vary without affecting the relative rankings. By determining a particular value's

threshold—beyond which the rankings of alternatives would change—the analysis identifies the degree to which the weighting of a particular value influences an alternative's ranking. This analysis is particularly useful when there may be some uncertainty in the weightings to be assumed in the analysis. Using the same simplified example as above, a weighting sensitivity analysis might show that, if the weightings were changed (over the range of uncertainty) such that the costs of implementation and maintenance were weighted more lightly, and technical effectiveness was weighted more heavily, Alternative A might achieve a higher total score and surpass Alternative B in rank. On the other hand, a weighting sensitivity analysis might show that, if the weightings were changed such that the costs of implementation and maintenance were weighted more lightly, and technical effectiveness was weighted more heavily, the total scores for both alternatives might remain very close, indicating that the ranking is insensitive to the weightings over the range of uncertainty.

Environmental Management System (EMS)

The City of Portland may develop an internal environmental management system, or EMS, for use in preparing and implementing the watershed management plans created through the watershed management process described in Chapter 3. The EMS would guide the detailed, day-to-day management activities needed to implement the *Framework* and would provide a structured, consistent approach to long-term watershed management.

The most commonly used EMS is an internationally accepted and proven management tool that was developed by the International Organization for Standardization (ISO). This EMS conforms to ISO 14001, which defines an EMS as part of an overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining environmental policies and strategic plans. In the City of Portland's case, the EMS would be structured to help the City achieve a desired level of environmental performance—that is, the achievement of the watershed goals, objectives, targets and benchmarks established for each of the watersheds, following the process described in Chapter 3.

The City's EMS, referred to as the Watershed Management System, or WMS, could be patterned after the ISO 14001 model. Ultimately, WMS would integrate the scientific principles, restoration guidelines and watershed health goals and objectives into the City's everyday operations. In this way, the watershed approach described in the *Framework* would become part of the daily responsibility for all employees of the City—not just those on watershed teams. Senior management would play a direct and active role in WMS by monitoring and measuring the City's progress toward its watershed health goals and continually looking for ways to improve its efforts.

Addressing Uncertainty

The City's watershed planning process embraces, rather than fights, the inevitable uncertainties associated with the analysis of complex interactions between biological and human systems. All models and analytical approaches are abstractions of reality subject to varying degrees of uncertainty. The key to effective analysis in an uncertain world is to frame an approach that recognizes that uncertainties will always remain in specific data, analyses and assumptions. In the City's watershed planning process, uncertainties will be addressed as follows:

- By clearly communicating the methods, strengths and limitations of each analysis.
- By explicitly identifying uncertainties and assumptions.
- By incorporating corroborative analyses to validate key conclusions independently. Results provided by each analytical approach will be corroborated with independent analysis using alternative methods. For instance, EDT projections of rearing densities from habitat conditions can be independently validated using empirical field observations. This way, the limitations of any single approach or model cannot drive conclusions, and all available information and tools can be incorporated. Some opportunities to corroborate tools will be elective and used on a case-by-case basis depending on time, resources and the perceived risk of not verifying uncertainty.
- By using analyses to identify the importance of uncertainties. Model sensitivity analyses will be used to evaluate the size of the response of the model to the variability of a particular model attribute. If a model is very responsive to a particular attribute and the attribute has been measured with a fair amount of uncertainty, then it is of value to invest in additional study to reduce that uncertainty. If the model is not responsive to the attribute, there is probably little value in reducing that uncertainty. In such a manner it can be determined which uncertainties are most important to reduce with focused data collection.
- By drawing conclusions based on the weight of all evidence rather than any specific analytical result, and by building in appropriate safety factors to buffer risks. A weight-of-evidence approach considers the net balance of all the evidence, rather than the specific certainty of individual observations. Safety factors are extra margins of protection for uncertain outcomes—for instance, engineers include safety factors in their calculations to overbuild structures to make sure they will hold up.

Acronyms and Abbreviations

ACWA	Association of Clean Water Agencies
ANPR	Advanced Notice of Proposed Rulemaking
BA	biological assessment
BE	biological evaluation
BES	Bureau of Environmental Services
B-IBI	Benthic Index of Biotic Integrity
BMPs	best management practices
BPA	Bonneville Power Administration
BOD	biochemical oxygen demand
CCI	committee for citizen involvement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIP	capital improvement program
CSO	combined sewer overflow
CWA	Clean Water Act
DEQ	Oregon Department of Environmental Quality
DHI	Danish Hydraulic Institute
DMA	designated management agency
DSS	Decision Support System
EDT	Ecosystem Diagnosis and Treatment
EFU	exclusive farm use
EMS	environmental management system
EPA	U.S. Environmental Protection Agency
EPT	ephemeroptera-plecoptera-trichoptera
ESA	Endangered Species Act
ESEE	economic, social, environmental and energy
ESRI	Environmental Systems Research Institute
ESUs	evolutionarily significant units
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
FR	Federal Register
GIS	geographic information system
HCP	habitat conservation plan

HEA	Habitat Equivalency Analysis
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
IHA	Indicators of Hydrologic Alteration
IPM	integrated pest management
IST	Independent Science Team
ITP	incidental take permit
LCDC	Land Conservation and Development Commission
LWG	Lower Willamette Group
MEP	maximum extent practicable
mg/L	milligrams per liter
MOA	memorandum of agreement
MS4	municipal separate storm sewer system
NEBA	Net Environmental Benefit Analysis
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service (now referred to as NOAA Fisheries)
NPCC	Northwest Power and Conservation Council
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Research Council
NRDA	natural resources damage assessment
NRT	Natural Resources Team
OAR	Oregon Administrative Rule
ODFW	Oregon Department of Fish and Wildlife
ORA	Oregon Revised Statute
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychorinated biphenyls
PFC	properly functioning condition
PPA	Performance Partnership Agreement
PPG	Performance Partnership Grant
PRP	potentially responsible party
RI/FS	remedial investigation and feasibility study
RRMT	River Renaissance Management Team
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SIC	Standard Industrial Classification
SLOPES	Standard Local Operating Procedures for Endangered Species
SPCR	Spill Protection and Citizen Response

TMDL	total maximum daily load
TRT	Technical Recovery Team
TSS	total suspended solids
UGB	urban growth boundary
UIC	underground injection control
USFWS	U.S. Fish and Wildlife Service
VSP	viable salmonid population
WMS	Watershed Management System
WQMP	water quality management plan
WRDA	Water Resources Development Act
WRI	Willamette Restoration Initiative
WWW-Net	Willamette Urban Watershed Network
WWTP	wastewater treatment plant

Glossary

Glossary

Note: Entries in this glossary are terms used in the *Framework for Integrated Management of Watershed Health*, defined as they are used in the context of the *Framework* and the City of Portland's watershed management activities.

4(d) rules or 4(d) limits: Special rules issued by NOAA Fisheries or U.S. Fish and Wildlife Service that establish "take" prohibitions and allow "take" of species listed under the Endangered Species Act when that "take" is connected with certain categories of activities that contribute to conservation of a listed species. A public or private entity may request that a program be recognized as an activity for which NMFS or the USFWS will "limit," or not apply, the "take" prohibitions.

Action: A specific project, activity or task that the City of Portland (or others) will conduct to improve watershed health.

Adaptive management: A dynamic planning and implementation process that involves applying scientific principles, methods and tools to improve management activities incrementally, as decision makers learn from experience and better information and analytical tools become available. Involves frequent modification of planning and management strategies — and sometimes goals, objectives and benchmarks— in recognition of the fact that the future cannot be predicted perfectly. Requires frequent monitoring and analysis of the results of past actions and application of those results to current decisions.

Adfluvial: Of, or relating to, fish that live in lakes and migrate to streams or rivers to spawn.

Alevin: In fisheries terminology, a larval salmonid that has hatched but has not fully absorbed its yolk sac, and generally has not yet emerged from the spawning gravel.

Allochthonous: Derived from outside a system, such as organic matter in a stream resulting from leaves from terrestrial plants.

Alluvial: Deposited by running water.

Ameliorate: To make better or more tolerable; to mitigate adverse effects.

Anadromous fish: Fish that hatch in freshwater, migrate to ocean water to grow and mature and return to freshwater to spawn; includes salmon, steelhead, and sea-run cutthroat trout.

Analytical tool: A tool for evaluating management alternatives; includes some computer models.

Annual hydrograph: A graph showing the trend in river or stream flow over a calendar year (January-December) or water year (October-September).

Aquatic habitat: The water-based locality or geographic area in which a plant or animal species naturally lives or grows.

Armoring: A barrier layer, frequently composed of boulders exposed as a result of clear water flushing downstream from a reservoir.

Artificial production: Spawning, incubating, hatching or rearing fish in a hatchery or other facility constructed for fish production.

Assets: Watershed conditions or features that are currently in a healthy, properly functioning state and that are considered key to sustaining important watershed functions.

At risk: Being susceptible to degradation or showing a trend toward degradation.

Autochthonous: Formed or originating in the place where found.

Bathymetric: Of, or relating to, the measurement of water depth at various places in a body of water.

Benchmarks: Specific outcomes in indicators that are to be achieved at particular times as the City of Portland progresses toward achieving established target values for those indicators.

Benthic macroinvertebarates: Organisms without backbones found on the floor of a stream or river. Benthic macroinvertebrates are a food source for fish.

Biological diversity (biodiversity): Variety of plant and animal life coexisting in a specific habitat.

Biota: The flora and fauna of a region.

Channelization: The act of cutting off side channels of a stream or river and artificially confining the channel.

Characterization: A thorough documentation of existing (baseline) and historical conditions within a watershed, along with anticipated trends in those conditions. Involves describing problems, watershed assets and the causes and sources of those problems and assets.

Clean Water Act: A law passed by the U.S. Congress in 1972 that makes illegal the discharge of pollution into surface or ground waters without a permit, and that encourages the use of the best achievable pollution control technology to reduce the impact of discharged effluent.

Combined sewer overflow (CSO): In areas with combined sewers (that is, sewers that convey both sewage and stormwater in a single pipe), the phenomenon of runoff filling sewer pipes to more than capacity, causing overflow of sewage and stormwater into a waterbody.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), or "Superfund": A law passed by the U.S. Congress that (1) created requirements concerning inactive hazardous waste sites, (2) provides for liability of persons responsible for releases of hazardous waste, and (3) established a trust fund to provide for cleanup when no responsible party can be identified.

Conduit: A restricted, human-made passageway such as a stream; a conduit is more limiting than a corridor.

Confluence: The junction or union of two or more streams; a body of water produced by the union of several streams.

Corridor: A linear natural area that provides connectivity between two or more nonlinear areas, primarily for wildlife needs.

Deme: A local population of closely related interbreeding organisms.

Diel: Involving a 24-hour period.

Ecological services: The functions that a natural resource provides to benefit the environment and human uses.

Ecosystem: The living and nonliving components of the environment that interact or function together; includes plant and animal organisms, the physical environment and the energy systems in which they exist.

Ecotone: A transition area between two adjacent ecological communities.

Ectotherm: A cold-blooded animal.

Eddies: Currents of water running counter to a main current.

Emigration: Permanent movement of individuals of a population away from the area occupied by that population to a new area.

Endangered Species Act: A law passed by the U.S. Congress in 1973 that established programs for the conservation of threatened and endangered plants and animals and the habitats in which they are found. The U.S. Fish and Wildlife Service maintains the list of threatened and endangered species.

Epifauna: Animals that live upon or are associated with substratum features.

Escapement: The number of salmon, steelhead and cutthroat that return to a specified point of measurement after all natural mortality and harvest have occurred.

Spawning escapement consists of those fish that survive to spawn.

Estuary: The part of the wide, lower course of a river where its current meets and is influenced by the ocean tides.

Extirpate: To destroy completely.

Fecund: Fruitful in offspring or vegetation.

Flow augmentation: Increased flow resulting from the release of water from storage dams or other sources.

Flow: The volume of water, often measured in cubic feet per second (cfs), flowing in a stream.

Genotype: All or part of the genetic constitution of an individual or group.

Geomorphologic: Relating to the form or surface features of the earth.

Goal: A statement of a desired end state for the watershed; the City of Portland's obligations and aspirations for achieving healthy watersheds.

Habitat Conservation Plan: A species protection plan, allowed by Section 10 of the federal Endangered Species Act, that permits the lawful "taking" of species listed as endangered as long as actions described in the plan meet the long-term goals for restoring the populations to a self-sustaining level. Applicants may devise a plan that mitigates the impact of their proposed activities, providing protections for listed species. Habitat conservation plans may occur at the local, regional or multispecies level, allowing for more comprehensive planning efforts.

Habitat creation: The process of creating habitat at a site where it did not exist historically; bringing into being specific environmental conditions that organisms depend on, directly or indirectly, to carry out their lives.

Habitat: The locality or geographic area in which a plant or animal species naturally lives or grows.

Harvest management: The process of setting regulations for commercial, recreational and tribal fish harvests to achieve a specified goal within a fishery.

Hatchery subsidy: The release of artificially produced salmonids from a contained, managed facility to the habitat of indigenous, naturally spawning salmonids.

Hydrograph: A graph showing the changing flow or depth of a body of water with respect to time.

Hydrophobic: Resistant to or not readily dissolved in water; lacking an affinity for water.

Hyporheic: Of, or relating to, groundwater that has a hydrologic connection to a stream.

Impervious surface: An impermeable ground coverage or surface, such as a paved road, roof, sidewalk or structure, that alters the natural flow and quality of water.

Independent Science Team: Leaders in the field of watershed and fisheries science, from throughout the Pacific Northwest, that have been assembled by the City of Portland to strengthen the *Framework for Integrated Management of Watershed Health* and other watershed-related work products by providing an independent peer review.

Indicator: A measurable attribute of the environment that represents some aspect of ecological function in the ecosystem, particularly if the ecological function is difficult to measure directly. A comprehensive set of environmental indicators can be used for monitoring the health and functioning of an ecosystem.

Indigenous: Native to the region.

Interannual: Of, or relating to, variation between years (for example, wet years and drought years).

Lacustrine: Of, or relating to, plant or animal matter formed in, living in or growing in lakes.

Lotic: Of, relating to, or living in actively moving water.

Metapopulation: A larger population composed of several local populations that are spatially separated but linked by migrants, allowing for recolonization of unoccupied habitat patches after local extinction events.

Metrics: The characteristics of an indicator that are measured to evaluate its condition.

Metro: The directly elected regional government that serves Clackamas, Multnomah and Washington counties and the 24 cities in the Portland, Oregon metropolitan area. Metro is responsible for the region's open space protections, parks management, land-use planning, garbage disposal management and recycling programs. Metro also manages such facilities as the Oregon Zoo and the Oregon Convention Center.

Mitigation: The creation, restoration or enhancement of a wetland area or other natural resource to maintain the functional characteristics and processes of the area, such as its natural biological productivity, habitats and species diversity; unique water features; and water quality.

Morphology: The study of the form and structure of animals and plants.

Natal fidelity: The quality or state of preferring to return to where one was born; refers to salmon returning to streams where they emerged and reared as fry.

Natal stream: The stream in which a salmon or trout originally incubated and reared, and to which it returns as an adult.

National Contingency Plan: The federal government's blueprint for responding to both oil spills and releases of hazardous substances. This policy was revised in CERCLA to promote overall coordination among the various levels of responders and contingency plans.

Natural area: A landscape unit composed of native plant and animal communities and their habitats, largely devoid of human-made structures and maintained and managed in such a way as to promote or enhance biological communities.

Natural Resources Damage Assessment: A process that allows the calculation of the monetary cost of restoring injuries to natural resources that result from releases of hazardous substances or oil. The U.S. Environmental Protection Agency is required to notify and coordinate with Natural Resource Trustees as specified in CERCLA.

Nested hierarchies: A ranked order, series or sequence formed such that each member, element or set is contained in or contains the next.

NOAA Fisheries: A division of the U.S. Department of Commerce having shared jurisdiction with the U.S. Fish and Wildlife Service, under the Endangered Species Act, to list most marine species, including anadromous fish, and to determine what constitutes the taking of listed species. Formerly known as National Marine Fisheries Service, or NMFS.

Normative ecosystem: An ecosystem in which specific functional norms or guidelines that are essential to maintain diverse and productive populations are provided.

Normative flow: A flow regime that provides characteristics of flow magnitude, frequency, duration and timing essential to support diverse and productive salmonid and other flow-dependent resources.

Not properly functioning: Being degraded to the point that the continued existence of a species is threatened; used describe one or more watershed conditions.

Objectives: Specific outcomes in watershed functions and conditions that must be achieved for watershed health goals to be attained; a measurable component of a goal. An objective is quantified where practicable.

Off-channel habitat: The physical environment necessary and natural to fish and other species that is located adjacent to or connected to the primary instream flow.

Oregon Department of Environmental Quality (DEQ): One of the state regulatory agencies responsible for the protection of Oregon's environment. DEQ's responsibilities include protecting and enhancing Oregon's water and air quality, for cleaning up spills and releases of hazardous materials and for managing the proper disposal of hazardous and solid wastes. The federal Environmental Protection Agency (EPA) delegates authority to DEQ to operate federal environmental programs within Oregon such as the federal Clean Air, Clean Water, and Resource Conservation and Recovery acts.

Oregon Department of Fish and Wildlife: Oregon's natural resource agency that manages the state's fish and wildlife resources.

Passage: The movement of migratory fishes through, around or over dams, reservoirs and other obstructions in a stream or river.

Phenotypic: Of, or relating to, the visible or behavioral properties of an organism that are produced as a result of the interaction of the genotype and the environment.

Predation: The act of preying.

Problems: Watershed conditions or features that are not properly functioning or that are contributing to impairment of watershed and river health.

Properly functioning condition: The sustained presence of natural habitat-forming processes that are necessary for the long-term survival of the species through the full range of environmental variation.

Reach: A section of stream between two specified points.

Reclamation: The process of putting a natural resource to a new or altered use to serve a utilitarian or human purpose. Often used to refer to processes that alter native ecosystems and convert them to agricultural or urban uses.

Reference conditions. Watershed conditions that reflect one of various reference states, such as actual historical conditions or the habitat's ecological potential, meaning the conditions that would exist if environmental habitat attributes were unimpaired and functioning properly.

Refugia: Locations and habitats that support populations of organisms limited to small fragments of their previous geographic range. Also refers to areas used by fish and wildlife for hiding and resting.

Rehabilitation: The process of restoring a natural resource or site to good condition or working order. Used primarily to indicate visual improvements to a natural resource.

Resident fish: Fish that do not migrate to the ocean but instead remain in freshwater for the entirety of their lives.

Riparian: Of, or relating to, the banks of a waterbody.

River Renaissance Management Team: A group of top managers from all bureaus within the City of Portland. The team brings an interdisciplinary focus and integration to bureau actions that address river-related activities and implement the five River Renaissance vision themes.

Scientific foundation: The body of evidence and peer reviewed study that describe ecosystem conditions needed to restore and maintain watershed functions and conditions and help guide decisions and actions that will result in desired ecosystem conditions across City watersheds; links all components of the *Framework for Integrated Management of Watershed Health*.

Scientific rationale: The body of science and research upon which all objectives, characterizations, analyses and planning are based; guides development of the objectives and actions.

Section 7: The section of the federal Endangered Species Act that regulates any action authorized, funded or carried out, in whole or in part, by federal agencies; requires the conservation of threatened and endangered species and the assurance that actions do not jeopardize listed species or adversely modify critical habitat.

Slough: An inlet on a river or a creek in a marsh or tide flat.

Spatio-temporal: Considering features of time and space in measurement.

Spill: (1) To release water through a spillway rather than through turbine units at a hydro-electric project; water released in such a way; (2) discharge (sometimes under an authorized permit, sometimes accidental) of a substance to a waterbody.

Stochastic: Pertaining to random or uncertain variables.

Strategies: Plans of action that will accomplish the goals and objectives and thereby fulfill a stated vision.

Subpopulations: Races and/or subspecies that, collectively, make up a population; genetically, a subcomponent of a population of a fish or wildlife species.

Substratum: The material underlying something, such as the soil beneath plants and animals.

Tailwater: Water below a dam or waterpower development.

Target value: A specific value established for an environmental indicator that represents the condition that the City of Portland will strive to achieve in order to meet its watershed health goals and objectives. A target value is based on what is necessary to achieve healthy watersheds, while taking into account aspects of the urban environment that, for practical purposes, are unchangeable.

Terrestrial: Living on or in or growing from land.

Thalweg: The bottom (at its deepest point) of any streambed or channel, natural or human-made.

Total maximum daily loads (TMDLs): A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources; the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources to ensure that the waterbody can be used for the purposes the state has designated.

Tributary: A stream feeding a larger stream or a lake.

Trophic levels: Relative positions within the food chain.

Trophic: Of, or relating to, nutrition.

U.S. Fish and Wildlife Service. The branch of the U.S. Department of Interior that is authorized to list plant and animal species—and the habitat on which they depend—for protection under the federal Endangered Species Act; has primary responsibility for terrestrial and freshwater species, including coastal cutthroat trout.

Water quality management plan: Plans for implementing state water quality standards for impaired (303 (d) listed) streams, as required by the Clean Water Act (CWA). The standards are driven by DEQ's total maximum daily loads (TMDLs) that are scheduled to become federally approved by 2007. Water quality management plans will implement these standards for Portland's impaired waterbodies and will be developed by the City of Portland, working closely with landowners, watershed councils and other stakeholders. These plans will become part of DEQ's overall statewide water quality management plan.

Watershed assets: Watershed conditions or features that are currently in a healthy, properly functioning state and that are considered key to sustaining important watershed functions.

Watershed: A topographically discrete unit or stream basin that includes the headwaters, main channel, slopes leading to the channel, tributaries and mouth area.

Wetland: Land areas where excess water is the dominant factor determining the nature of soil development and the types of plant and animal species living at the soil surface. Wetland soils retain sufficient moisture to support aquatic or semi-aquatic plant life.

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