BEST AVAILABLE SCIENCE REVIEW AND CRITICAL AREA EVALUATIONS/ CHARACTERIZATIONS

City of Lake Stevens
Critical Areas Update

Prepared for
City of Lake Stevens

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I. INTRODUCTION

I.1 Background

The Washington State Growth Management Act (GMA) requires that cities and counties review and, if necessary, revise their development regulations every 5 years. The Washington Administrative Code (WAC) 365-195-900 requires that cities and counties include the "best available science" when developing policies and regulations to protect critical areas, and give "special consideration" for conservation of anadromous fish. The Washington State Office of Community Development (OCD), under the authority of the GMA, developed procedural criteria for adopting and revising comprehensive plans and developmental regulations. These criteria include new regulations regarding Best Available Science (BAS) (WAC 365-195-900 through 925). The regulations address the following topics:

- Defining BAS
- Recommendations as to where local governments can obtain BAS
- Criteria for demonstrating that BAS has been included in the development of critical areas policies and regulations
- What to do in the absence of sufficient scientific information
- Meaning of "special consideration" for the protection of anadromous fish, and criteria for demonstrating that special consideration has been given

The City of Lake Stevens is now revising its critical areas regulations in accordance with the GMA requirements. Many of the proposed revisions are specifically developed to minimize the potential impacts of development on salmonid habitat, with special emphasis on Endangered Species Act (ESA)-listed species. URS has conducted a BAS review of the Lake Stevens critical areas regulations related to wetlands, streams, and fish and wildlife habitat and has provided an evaluation/characterization of each. Field visits were conducted in November and December 2006 to verify existing conditions within the City (including recent Northlake Annexation area).

I.2 Organization of This Report

The objectives for this BAS review include two tasks:

1. Provide a general characterization of stream and other surface waters and wetlands and their functions and values, including streams supporting anadromous species within the city limits (does not include Urban Growth Area). Overall wetland and fish and wildlife habitat evaluations, as applicable, are incorporated into the characterization.

2. Compile the BAS for those elements (this was also completed for versions of the code in March 2006 and January 2007).

II. Evaluation and Characterization

This section provides a general evaluation and characterization of streams and other surface waters, including streams supporting anadromous species within the city limits, and wetlands and their functions and values based on the inventory information available at the City of Lake Stevens, State databases, site specific and regional reports, and very limited reconnaissance. The features are organized and discussed in terms of the current classifications used in best available science documents. Overall wetland and fish and wildlife habitat evaluations, as applicable, are incorporated into the characterization.

II.1 Streams and Other Surface Waters

Type S waters include lakes and streams inventoried as "shorelines of the state." Stevens/Catherine Creek downstream from the confluence of the Lake Stevens Outlet Channel (also called Stevens Creek) and Catherine Creek is the only stream reach within the City of Lake Stevens designated as Type S water (WAC 173-18-350). Lake Stevens, designated as a lake of statewide significance, is the only other Type S water within the City of Lake Stevens (WAC 173-20-650). City Critical Areas Maps are included in Appendix A. One field visit was conducted in 2005 and another was conducted on November 22, 2006 to further verify and update the earlier information.

II.1.1 Existing Stream Habitat and Species Characterization

For the purposes of this report, the outlet of Lake Stevens (Type F anadromous stream) downstream to the confluence with Catherine Creek at Hartford Drive will be referred to as Stevens Creek and the portion of the Creek from the confluence of the outlet reach of Stevens Creek and Catherine Creek downstream from Hartford Road (Type S anadromous stream) will be referred to as Stevens/Catherine Creeks. Catherine Creek (Type F anadromous stream) refers to the main channel upstream from the confluence of Stevens Creek (outlet reach of Stevens Creek) immediately above Hartford Drive. An unnamed intermittent tributary (Type F anadromous stream) that enters the City of Lake Stevens at Highway 92, drains connected perennial wetlands and ponds within the city and enters Catherine Creek on the left (east) bank immediately upstream of Catherine Drive. Springbrook Creek (Type F) draining off a hillside to the west of Grade Road enters Catherine Creek on the right (west) bank at approximately halfway between 32nd Place and 36th Street. Less than 100 feet upstream of its confluence with Catherine Creek, Springbrook Creek flows through an impassable culvert. Anadromous fish only have access to the portion of Springbrook Creek below the culvert, with resident coastal cutthroat trout occurring upstream of the culvert. A drainage ditch in an old agricultural field north of Hartford Drive enters Catherine Creek on the right (west) bank just upstream of Hartford Drive. A tributary (Type F stream) flows north from its source, the outlet of a small pond located southeast of the corner of 16th Street and 127th Avenue, crosses 18th Street and flows through a ditch along the east side of 125th Avenue to 20th Street, and enters the outlet portion of Stevens Creek on the right (southeast) bank a short distance downstream from the intersection of Grade Road and Hartford Drive (across from the Fire Station). An ephemeral tributary (Type Ns) of the previous stream, draining a ravine east of 123rd Avenue, is shown on the Critical Areas Map to enter the south end of the pond located southeast of the corner of 16th Street and 127th Avenue, however there does not appear to any surface channel feeding the pond and any flow into the pond is likely sheet flow. This ephemeral tributary also appears to have an alternate channel, flowing northwest, in a ravine that ends in the vicinity of Bond Field. The channel of the ephemeral tributary appears to have historically traversed south from the end of the ravine and entering the stream that flows from the pond southeast of the corner of 16th Street and 127th Avenue about a hundred feet north of 16th Street. A field visit was made on November 22, 2006 (See Appendix B, BAS Field Visit), during a period of heavy rainfall, and only small pools were observed, with no flow present. Another ephemeral tributary (Type F stream) flows a short distance from a spring source through Catherine Creek Park and enters Stevens/Catherine Creek on the right (west) bank, just downstream from 20th Street. This stream is very small and only provides fish rearing habitat in the lower 150 feet of stream downstream from a park trail. Kokanee Creek (also called Mitchell Creek), a Type F non-anadromous stream, flows off a hillside into the north end of Lake Stevens from a completely urbanized drainage basin. The lower portion of Kokanee Creek that is utilized by spawning kokanee salmon flows alongside the east side of Mitchell Road.

Two Type F anadromous streams, Stevens and Lundeen Creeks, enter the City of Lake Stevens at Highway 92 and flow south to Lake Stevens, where they enter the lake at its northwest corner. Stevens Creek is the portion of Stevens Creek, upstream of Lake Stevens, but Stevens and Lundeen Creeks are roughly comparable in size and are the largest tributaries of Lake Stevens.

Stevens Creek is west of Lundeen Creek and flows south between Lake Drive and 99th Avenue NE. Most of the riparian corridor within the city is still intact, except the reach that flows through a concrete lined channel between Vernon Road and the lake. Vernon Road and Lundeen Parkway appear to parallel each other where they cross Stevens and Lundeen Creeks. This section of road will be referred to as “Vernon Road” in this report. Residential housing consists of houses constructed in close proximity to Lake Drive and 99th Avenue NE. Residential yard generally do not intrude into the riparian corridor of the stream. There are culverts where Stevens Creek is crossed by Highway 92, 31st Place NE, and Vernon Road. The outfall of the culvert under Vernon Road is a partial barrier to spawning salmonids entering the stream from Lake Stevens. The culvert at North of 31st Place NE also is a partial barrier to fish passage. Despite partial blockages at these culverts, coho and kokanee salmon have been observed by Snohomish County staff as far upstream as Highway 92 (Snohomish County 2001). A perennial tributary (Type F), crosses Highway 92 approximately 200 feet east of Lake Drive and flows southeast, entering Stevens Creek on the right bank, about 500 feet upstream of 31st Place NE. The riparian corridor of this stream is intact, but two artificial ponds constructed a short distance below Highway 92 and halfway between the highway and the tributary’s confluence with Stevens Creek are complete barriers to anadromous coho salmon and lake-run kokanee salmon and coastal cutthroat trout. Only resident fish occur upstream of the weir at the first pond.

Lundeen Creek flows south between 101st Avenue NE and Callow Road. Most of the riparian corridor within the city is still intact, With the exception of a reach that flows through a roadside ditch along side 101st Avenue, most of the riparian corridor within the city is still intact. The reach flowing through the roadside ditch is scheduled to be rerouted to its original channel in the future to minimize flooding and improve fish habitat. Residential housing consists of houses constructed in close proximity to Catlow Road, and 101st Avenue NE. Residential yard generally do not intrude into the riparian corridor of the stream. There are culverts where Lundeen Creek is crossed by Highway 92, 30th Place NE, and Vernon Road. None of these culverts are barriers to fish passage and coho and kokanee salmon have been observed by Snohomish County staff as far upstream as Highway 92 (Snohomish County 2001). A perennial tributary (Type F), enters Lundeen Creek on the left bank about 150 feet upstream of Vernon Road. This tributary has several small tributaries and flows off a plateau south of Highway 92, east of Callow Road, west of 109th Avenue NE, and north of Oak Road. The tributary flows off the plateau through a ravine along the southeast side of Oak Road, crossing Callow Road at the downstream end of the ravine. Most of the riparian corridor of this tributary within the city is still intact. The culvert at Callow Road is a complete barrier to fish passage, with anadromous coho salmon and lake-run kokanee salmon and coastal cutthroat trout occurring below the culvert and only resident fish present upstream of the culvert.

Information about the existing environmental conditions of the Lake Stevens/Catherine Creek watershed and the distribution of fish species within the watershed discussed below were obtained from available site specific environmental reports (R2 2000, DID8 1999, Cornwall 1995, Harling 2002, Jagt 2004, J&S 1994, Marczin, 1999, Mueller 1997, Pfeifer 1978, Berge and Higgins 2003).

The upper portion of Catherine Creek within the city limits flows through the Lake Stevens Woods and Williams Woods Residential Developments. Most of the riparian buffer along Catherine Creek and its tributaries consists of native shrubs and medium sized trees or forested wetlands, with small to medium sized western redcedar (*Thuja plicata*), red alder (*Alnus rubra*), black cottonwood (*Populus balsamifera*), western hemlock (*Tsuga heterophylla*), and Douglas-fir (*Pseudotsuga menziesii)* the dominant tree species. There is a dense understory of shrubs, including salmonberry (*Rubus spectabilis*), hardhack (*Spiraea douglasii*), cascara (*Rhamnus purshiana*), red elderberry (*Sambucus racemosa*), Pacific ninebark (*Physocarpus capitatus*), and willows (*Salix* spp.). Ground cover includes skunk cabbage (*Lysichiton americanum*), sword fern (*Polystichum munitum*), reed canary grass, cattails (*Typha latifolia*), creeping buttercup (*Ranunculus repens*), and small-fruited bulrush (*Scirpus microcarpus*) dominating the understory of the forested community. Between the urbanized upper reaches of Catherine Creek within the city limits and Hartford Drive, lower Catherine Creek is channelized and flows through an agricultural field, with the riparian vegetation dominated by reed canary grass (*Phalaris arundinacea*). Catherine Creek supports spawning populations of coastal cutthroat trout (*Oncorhynchus clarki clarki*) and coho salmon (*O. kisutch*), federally listed as a candidate species under the Endangered Species Act (ESA) and may also support a few chum salmon (*O. keta*). Most of the salmonids occurring in the mainstem of Catherine Creek are young-of-the-year (YOY) with almost no older rearing salmonids present. Yearling coho have been documented in a small side channel and the connected wetlands of the unnamed tributary of Catherine Creek. Coho salmon spawners have been observed in the unnamed tributary as far upstream as 36th Street. In addition to salmonids, two species of sculpins (*Cottus* sp.) and three-spine stickleback (*Gasterosteus aculeatus*) have been documented during surveys of the stream. Only coho YOY and yearlings have been documented in the unnamed tributary of Catherine Creek. Springbrook Creek contains YOY coho salmon and coastal cutthroat trout. The drainage ditch draining from an old agricultural field into Catherine Creek does not contain fish.

Coho salmon, kokanee, and coastal cutthroat trout have been documented to occur in Lundeen and Stevens Creeks throughout the reach of the streams within the City of Lake Stevens (Snohomish County 2001, Haring 2002). Tributaries of Stevens and Lundeen Creeks contain the above species below barriers to anadromous fish passage and resident coastal cutthroat trout above the barriers (Haring 2002). Most of the riparian buffer along Stevens and Lundeen Creek and their tributaries is similar to that of Catherine Creek, consisting of native shrubs and medium sized trees or forested wetlands.

Only kokanee salmon (*O. nerka*) have been documented in Kokanee Creek, but coastal cutthroat trout were observed during a site visit by a URS biologist on November 22, 2006. The entire drainage of Kokanee Creek is occupied by residential development, and the stream flows primarily through areas of mown lawns or along Mitchell Road, with only a fragmented riparian zone of low growing shrubs and small trees. Kokanee Creek has two forks, with kokanee salmon spawners observed as far upstream as 20th Street on the west fork and 19th Street on the east fork. The kokanee present in Lake Stevens tributaries were likely transplanted in 1912 or 1913 from the Lake Washington tributary of Bear Creek (a tributary of the Sammamish River) or late spawning Lake Sammamish kokanee from a Lake Sammamish tributary stream; however, no genetic analysis has been done between Lake Stevens kokanee, Bear Creek Kokanee, and late spawning Lake Sammish kokanee. If the original source stock of Lake Stevens kokanee was Bear Creek, they may represent the last surviving stock of Lake Washington kokanee. It has also been suggested that kokanee are native to Lake Stevens, but this has not been verified through genetic analysis.

The outlet reach of Stevens Creek has been documented during electrofishing surveys to contain coho salmon YOY, sculpins, pumpkinseed sunfish (*Lepomis gibbosus*), and western brook lamprey (*Lampetra richardsoni*). The Type F tributary of Stevens Creek that flows out of a pond southeast of the corner of 16th Street and 127th Avenue has a relatively intact forested riparian zone similar to that of upper Catherine Creek and Stevens/Catherine Creek downstream from 20th Street. The streambanks in the downtown area of the City of Lake Stevens are armored with riprap, with only grass and low-growing vegetation between Hartford Drive and the bank of the stream. The bank opposite of Hartford Drive contains occasional small willows and is dominated by a shrub community dominated by invasive, non-native plants such as Himalayan blackberry (*Rubus procerus*) and purple loosestrife (*Lythrum salicaria*). The pond that feeds this tributary receives occasional plants of sports fish and salmonids, including coho salmon, have been observed in the stream.

Stevens/Catherine Creek is likely to contain the same species as documented in Stevens Creek above the confluence of Catherine Creek, with pumpkinseed gradually disappearing in the downstream reaches. In addition, YOY coastal cutthroat trout are likely present in pool habitat and yearling coastal cutthroat trout and coho salmon are probably present during the winter and spring, and three-spine stickleback are probably present. Mountain whitefish (*Prosopium williamsoni*) have been documented to occur in Lake Stevens and in the Little Pilchuck River and probably occasionally occur in Stevens and Stevens/Catherine Creeks. In addition, spawning steelhead trout (*O. mykiss*) and chum salmon that have migrated through Stevens/Catherine Creek and the outlet reach of Stevens Creek have been observed in Lake Stevens and may occasionally enter Catherine Creek. The riparian community of Stevens/Catherine Creek is similar to that of the upper reaches of Catherine Creek within the city limits, however many of the trees (particularly in the vicinity of Catherine Creek Park) are feet high or higher with trunks 20 to 30 inches in diameter at breast height. The Type F ephemeral tributary of Stevens/Catherine Creek that flows through Catherine Creek Park does not contain fish, but may provide winter refuge habitat for coho salmon and coastal cutthroat trout. This tributary flows through a relatively intact forested riparian zone of mature conifer forest in Catherine Park.

The stream flowing through a ravine above Bond Field was the only Type Ns Stream observed during site visits by a URS biologist. Because of the low gradient of streams within the City of Lake Stevens, most stream channels are accessible to anadromous fish or contain resident fish above barriers. Other Type Np (perennial non-fish) or Ns (intermittent or ephemeral non-fish) stream reaches were not identified, but they may exist within the City of Lake Stevens, in the upper reaches of the left bank tributary of Lundeen Creek upstream of Oak Road if there are reaches above natural fish passage barriers with no fish present. Type Ns stream reaches were not identified, but they may exist within the City of Lake Stevens in the upper reaches of the ephemeral tributaries of Lundeen, Stevens, and Stevens/Catherine Creek if natural fish passage barriers are present.

II.1.2 Stream Channel Characteristics

Lundeen Creek, Stevens Creek (within the boundaries of the City of Lake Stevens), and Catherine Creek flow through a region with very little topographic relief. The gradient of the channel is low (generally 1% or less) and most of the stream channel is incised 10 to 15 feet. There are a few steeper gradient reaches of Kokanee and Springbrook Creeks, but the only stream channel flowing through a ravine is the portion of the Lundeen Creek left bank tributary that flows along side Oak Creek Road. In most reaches, there is no floodway and, with the exception of unchannelized portions of Lundeen Creek, Stevens Creek above Lake Stevens, Stevens/Catherine Creek below 20th Street NE, and a reach of Catherine Creek about 2,200 feet in length above Hartford Drive, the streams are confined to a narrow incised channel of 8 to 18 feet in width (3 to 8 feet for upper Stevens Creek and Lundeen Creek above Lake Stevens). In most reaches the stream banks are stable and composed of sand and gravel. With the exception of reaches of the Stevens and Catherine Creeks in the vicinity of Hartford Drive where sand and silt dominates, the substrate of Stevens and Catherine Creeks is composed of gravel. Kokanee Creek flows from a hillside into Lake Stevens, with the portion of the creek most heavily utilized by spawning kokanee salmon a straight channel running alongside the road. The channel has been modified from a 4% gradient to a 2% gradient channel through the use of a log-weir/step-pool design. The banks of the Lake Stevens outlet portion of Stevens Creek along Hartford Road and above the confluence of Catherine Creek and Kokanee Creek along Mitchell Road have been riprapped to maintain the structural integrity of the roadway and stabilize the streambank, with no room available to maintain a riparian buffer or trees between the road and the stream channel.

II.1.3 Riparian Buffer Functions

Stream riparian buffers are intended to maintain riparian and stream functions such as erosion control; removal of fine sediment and pollutants from runoff; large woody debris recruitment; stream water temperature moderation; maintenance of benthic macroinvertebrates (primarily aquatic insects and crustaceans) habitat; salmonid instream habitat; and riparian/aquatic wildlife communities; maintain microclimate for riparian wildlife, maintain stream channel structure, and maintain connectivity between fish and wildlife habitat areas by providing corridors for the movement of fish and wildlife. With the exception of large woody debris (LWD) recruitment and the protection of riparian wildlife habitat and riparian microclimate, a review of best available science indicates that riparian buffers of about 99 feet are adequate to achieve approximately 80% of these functions (URS 2000, 2001). The review indicated that riparian buffers of about 131 feet are adequate to achieve 80% of LWD recruitment function. Murphy and Koski (1989) estimated that nearly all LWD is derived from within 99 feet of streams and 95% within 65 feet of the stream bank. McDade *et al.* (1990) estimated that 85% of LWD originates within 99 feet of stream banks and 50% within 33 feet. Riparian wildlife habitat and microclimate functions can require buffers as great as 656 feet to achieve about 80% functionality, but these requirements are highly variable and depend upon wildlife species and edge effects (predation from feral animals and forest edge species on riparian and forest wildlife, lower soil and air humidity, modification of riparian plant communities by invasive plant species). Buffer widths for LWD recruitment are usually based on a general average tree height of about 130 feet for mature conifer forests in the northwest, making the assumption that trees that fall further than 130 feet from a stream channel are unlikely to be delivered into the stream.

The City of Lake Stevens buffers for Type S and Type F streams are intended to maintain riparian functions necessary to protect instream habitat for fish. Type S streams are always perennial and generally contain salmonids in western Washington. In many cases, Type S streams contain anadromous or federally listed salmonids. None of the Type S streams within the City of Lake Stevens contain listed salmonids, but steelhead trout (proposed for listing as threatened) are present in all Type S streams within the City of Lake Stevens. Type F streams either contain fish or provide seasonal habitat for fish. Perennial Type F streams in the City of Lake Stevens contain salmonids and frequently contain anadromous salmonids. Steelhead trout (proposed for listing as threatened), have been documented to enter Lake Stevens and likely spawn in Stevens and Lundeen Creeks. These streams require riparian buffers adequate to protect the full range of riparian functions necessary to maintain instream and riparian habitat necessary for the survival of salmonid fishes. City of Lake Stevens buffers for Type S and Type F streams are consistent with BAS.

Type Np (perennial) and Type Ns (intermittent) streams are non-fish bearing under WDNR stream typing, but can provide habitat for aquatic wildlife, such as macroinvertebrates and amphibians. Type Np and Ns streams can contain non-salmonid fish under City of Lake Stevens stream type classifications. Riparian buffers on Type Np and Type Ns streams are primarily designed to maintain water quality in both non-fish bearing streams and the fish-bearing streams that they flow into. Non-fish bearing Type Np and Type Ns streams can also provide nutrients and LWD to downstream reaches, which contain fish and support macroinvertebrates, which contribute to fish-bearing streams through downstream drift. City of Lake Stevens buffers for Type Np and Ns streams are at the low end of the range to be consistent with BAS for streams containing fish and at the high end of the range to be consistent with BAS for non-fish streams.

Drainage ditches are constructed vegetated swales and ditches that were never a natural stream channel, whose primary purpose is to convey stormwater from urban areas and agricultural fields to stream channels. Drainage ditches are man-made channels, rather than “ditched” natural stream channels that have been straightened and dredged into a uniform channel.

The 99-foot riparian buffers consistent with BAS literature are general requirements and may not contribute significantly more to the protection of riparian functions near fish-bearing streams in the City of Lake Stevens buffers. This is due to the nature of available habitat within urban areas and the stream morphology and surrounding terrain of streams within the city boundary.

Moderation of Stream Water Temperature

Shading provided by riparian canopy cover is the major factor that minimizes heating of stream water by absorption of solar radiation. Canopy shade is provided by shrubs and trees growing within 65 feet of stream banks, and vegetation greater than 65 feet from stream banks does not significantly affect stream temperatures (URS 2000, 2001). Studies indicate that buffer strips only need to be wide enough to include trees contributing to canopy cover. A 33 foot wide strip is adequate for shade. Since blockage of direct insulation by foliage is of primary importance, buffers of narrow streams may be less than 33 feet and dense shrubs can provide riparian shade for smaller streams (Barton *et al.* 1985).

Catherine Creek above the confluence with Stevens Creek derives most of its summer flow from cold groundwater. Summer flows are no more than a few gallons/minute and little pool habitat exists for fish. As a result, this reach of the stream primarily serves as a spawning stream for coastal cutthroat trout and coho salmon, with almost all juvenile fish migrating downstream to suitable summer habitat in the Little Pilchuck River during the spring. Current summer stream temperatures of Catherine Creek within the city limits are moderated by inflow of cool groundwater, and temperatures do not exceed 61°F (well within the tolerance range of native coho salmon, coastal cutthroat trout and other native fishes). With the exception of a channelized reach of about 2,500 feet flowing through a field just upstream from Hartford Drive, canopy closure of Catherine Creek ranges from 25% to 50%, and a 65 foot buffer is adequate to maintain the existing summer water temperature regime. Salmonid populations in Catherine Creek within the city limits are primarily limited by a lack of streamflow and pool habitat. An abundance of loose gravel and some available side channel and connected wetland habitat provides spawning habitat for coho and cutthroat trout, but little or no summer rearing habitat, forcing juvenile fish to migrate downstream to Stevens/Catherine Creek by spring.

Summer water temperatures in Stevens Creek and Stevens/Catherine Creek below Hartford road are controlled by the warm surface water outflow from Lake Stevens. Almost all of the summer stream flow of 2 to 3 cubic feet per second (cfs) comes from the outflow of the lake. Water temperature at the surface of Lake Stevens and in the outlet (Stevens Creek) can reach 78°F, exceeding the thermal tolerances of coho salmon and cutthroat trout. Although riparian canopy cover has been documented to prevent or minimize stream temperature increases due to solar radiation, it does not provide a cooling effect (Boyd and Sturdevant 1996). Any cooling that is likely to occur would be from groundwater entering the stream channel, which contributes only a small portion of the flow in Stevens/Catherine Creek and Stevens Creek during the summer months (Moore 2001, Boyd and Sturdevant 1996). Coho salmon and cutthroat trout young of the year (YOY) present in these streams in spring migrate downstream to the Little Pilchuck River during the summer when water temperatures exceed their thermal tolerances, regardless of available rearing habitat. As a result, shade from riparian canopy is not a significant limiting factor for Stevens and Stevens/Catherine Creek.

Kokanee Creek is primarily utilized by kokanee salmon which spawn during late fall and early winter freshets and migrate downstream to Lake Stevens soon after emerging from the gravel in the early spring. Summer flows in Kokanee Creek consist of subsurface interflow that averages 0.004 cfs and as a result is not utilized by fish during the summer months, minimizing the need for the shade function of riparian cover. In addition, the stream channel of the stream is less than 3 feet in width and surrounded by a dense shrub layer that provides an effective canopy during the summer months.

Riparian buffers of 65 feet for fish bearing streams and Np streams that drain into fish bearing streams are adequate to maintain stream temperatures, and riparian buffers will not prevent high stream temperatures in Stevens or Stevens/Catherine Creeks because of the influence of surface water input from Lake Stevens. Ns streams do not convey surface water during the summer months, so shade does not contribute to temperature moderation in these streams. In Catherine Creek, a lack of summer habitat, rather than summer stream temperatures is the limiting factor for salmonids.

Recruitment of LWD

Forested portions of stream channels in urban areas contain mostly deciduous trees much less than 100 feet tall. Larger mature trees tend to develop windshake and unsound limbs and are usually removed from urban areas as safety hazards. Large woody debris (LWD) in stream channels in urban areas often presents a severe hazard to bridges and other infrastructure during flood flows and must often be removed from stream channels. Due to streams flowing through narrow incised channels with few or no floodways and with no slopes present outside of the incised channels, there is no opportunity for LWD to roll into stream channels. Trees outside of a 50 foot buffer are unlikely to reach stream channels and if the upper portions of trees do fall into the stream channel, they do not include the trunk or root wad (the most valuable LWD). Areas with open vegetation in agricultural and residential areas contain few or no trees within 100 feet. Deeply incised stream channels and narrow floodways allow for very little lateral channel migration. Bank cutting, which is the delivery agent for LWD 31% (Lienkaemper and

Swanson 1987) of the time is rare. Windthrow is the primary delivery agent for LWD within urban areas such as within the city limits, and due to asymmetry of the rooting environment in proximity to a stream channel and the tilt of trees growing into the open canopy space above a channel, LWD delivery usually occurs in close proximity to stream banks. Stream channels of moderate gradient streams with steep sideslopes in western Washington and Oregon derive 11% of LWD from within 3 feet of stream channels, 50% from within 33 feet, 70% from within 65 feet and 85% within 99 feet of the stream channel (McDade *et al.* 1990). In the case of the narrowly incised stream channels and flat sideslopes of streams within the City of Lake Stevens, almost all LWD recruitment occurs within a few feet of the incised stream channel. Riparian buffers of 50 feet for fish bearing streams and 25 feet for non-fish bearing streams are adequate to maintain LWD recruitment.

Maintenance of Channel Structure

The influence of LWD on pool formation changes with channel slope. Analysis of pool forming mechanisms indicates that low gradient channels, such as those of streams within the city limits, are less sensitive to LWD abundance because pools are formed by mechanisms other than LWD when LWD abundance is low (Beechie and Sibley 1997). Stream banks within the City Limits, with few exceptions are stable, despite the fact that stream banks are primarily composed of poorly consolidated sand and gravel. It appears that the existing riparian vegetation is sufficient to stabilize stream banks. As described above, there is little potential for recruitment of LWD from beyond a short distance from stream banks within the city limits. Riparian buffers of 50 feet for fish-bearing streams and 25 feet for non-fish bearing streams are adequate to maintain existing channel structure.

Removal of Fine Sediment and Pollutants

Stream banks within the city limits are mostly stable, and contribute little fine sediment to stream channels. There is no indication that flooding has affected areas beyond 50 feet from stream channels and beyond 25 feet from smaller intermittent streams. In addition, urbanized lands have only modest sediment yields, particularly where steep slopes do not exist to contribute to a high landslide rate and efficient sediment delivery to stream channels. Most of the existing fine sediments in Stevens and Stevens/Catherine Creeks are delivered from the banks of the outlet channel of Stevens Creek or directly from stormwater runoff through storm drainage systems. Future developments will require stormwater treatment and detention that allows fine sediments to settle out of suspension before delivery to the stream channels. Stormwater detention systems should also prevent or minimize additional increases in peak flows from stormwater runoff. Treatment of stormwater runoff from roads and impervious surfaces and directing stormwater runoff through bioswales will minimize direct runoff of pollutants. Riparian buffers of 50 feet for fish-bearing streams and 25 feet for non-fish bearing streams are adequate to maintain or reduce current levels of fine sediment or pollutant delivery to stream channels. An exception may occur in the smaller and higher gradient streams draining off Walker Hill (Kokanee and Springbrook Creeks), where narrow incised channels carry large stormwater flows through channels with poorly stabilized stream banks and narrow riparian areas. However, most of this area has already been developed and any new developments will have to meet the new buffer width standards and other means of mitigation can be used to minimize erosion, such as creating lower gradient sideslopes and wider floodways for the stream channels.

Maintenance of Benthic Macroinvertebrate Habitat

As stated above, LWD recruitment will not be affected by riparian stream buffers of 50 feet for fish-bearing streams and 25 feet for non-fish bearing streams. These buffers should also be adequate to maintain or reduce current levels of fine sediment delivery to stream channels, and stream temperatures will not be affected. Much of the organic material utilized by primary producers (aquatic organisms that feed on algae and detritus) comes from leaf fall. Most of this leaf fall comes from shrubs and trees growing within close proximity to streambanks, with little contribution from trees further than 20 to 50 feet from banks. Riparian buffers of 50 feet for fish-bearing streams and 25 feet for non-fish bearing streams are adequate to maintain existing benthic macroinvertebrate habitat.

Maintenance of Aquatic Salmonid Habitat

As stated above, the proposed stream riparian buffers are adequate to maintain existing channel complexity and substrates. Available cover from existing LWD and riparian vegetation will not decrease, and forage from existing aquatic macroinvertebrate and terrestrial macroinvertebrate communities will not be reduced. The presence or absence of riparian canopy does not seem to be of any practical importance in terms of the amount of preferred food available to salmonids. Riparian buffers of 50 feet for fish-bearing streams and 25 feet for non-fish bearing streams are adequate to maintain existing salmonid habitat. Proposed buffers are wider than required to maintain existing salmonid habitat and will allow for habitat recovery above the current baseline.

Maintenance of Riparian Microclimate

Buffers of 328 to 656 feet are required to maintain forest interior microclimates for forest interior plant and wildlife species (Bolton and Shellberg 2001). Forest edge effects include lower atmospheric humidity, higher summer temperatures and lower winter temperatures, and lower soil moistures than interiors. This can affect the success of plant species utilized as forage by forest interior species. Burrowing animals that are easily desiccated in arid environments, such as salamanders and western toads, depend upon high moisture soils and high atmospheric humidity. However, current conditions within the city limits do not provide any habitats that provide these microclimate conditions, and no adjacent areas with those conditions could be linked to habitat areas within the City. The proposed riparian buffers will maintain existing habitat conditions for the affected forest interior species.

Maintenance of Habitat Connectivity and Wildlife Habitat

Stream riparian buffers provide a linear strip of forest and shrub habitat that serves as a travel corridor for some mammals, amphibians, and birds. However, many of these corridors do not connect to patches of forest habitats. In addition, corridors can increase mortality rates of migratory forest interior species by subjecting them to increased levels of predation from forest edge species. Studies of forested stream buffers suggest that buffers need to be between 328 and 656 feet wide in order to limit negative population effects to forest interior birds, such as nest predation due to the proximity of forest edge species (Bolton and Shellberg 2001). This assumes that forest birds will use riparian buffers and that bird use is correlated to buffer width, neither of which has been shown. A study of the effects of riparian areas around small streams indicated no discernible effect of bird diversity by the riparian stand. Riparian habitat along small streams is usually insufficient to support large animals, such as deer. Recent studies have shown that small mammal population numbers are not adversely affected by current riparian buffer sizes, at least in the short term. The species diversity of birds does not differ significantly between stream buffers of 46, 122, and 230 feet in width (Kinley and Newhouse 1997). For riparian corridors to successfully maintain forest interior species, they must connect to habitat patches of 30 to 80 acres in size, with 100-acre patches to maintain large mammals. Since forested habitat patches of 30 to 100 acres in size do not exist in the vicinity of the City of Lake Stevens for riparian buffers to connect, it is unlikely that riparian buffers/corridors will maintain populations of large mammals or forest interior species of small mammals and birds. Proposed riparian buffer widths are adequate to maintain the existing diversity of wildlife within the City of Lake Stevens boundaries. The existing wildlife community will continue to be dominated by forest edge and riparian species, with few of the forest interior associated species, such as insectivorous, cavity-nesting birds, northern flying squirrels (*Glaucomys sabrinus*) or Douglas Squirrels (*Tamiasciurus douglasii*). Omnivorous and fruit-eating birds, such as European starling (*Sturnus vulgaris*), American robin (*Turdus migratorius*), house sparrows (*Passer domesticus*), and raccoons (*Procyon lotor*) will dominate. The aggressive introduced cavity nesting birds (house sparrows and European starlings), will exclude native cavity nesting birds.

II.2 Wetlands

II.2.1 Wetland Buffer Evaluation

Buffers, in the context of wetland protection, are vegetated upland areas immediately adjacent to the wetland. Most buffer regulations focus almost exclusively on how wide buffers should be. Many literature searches have been published summarizing the effectiveness of various buffer widths (e.g., Castelle et al., 1992; Castelle and Johnson, 2000; Desbonnet et al., 1994; FEMAT, 1993). Following is a brief summary of some of that literature, which included studies conducted in agricultural, silvicultural, and urban riparian settings throughout the United States and Canada. The literature was reviewed to evaluate the relationships between buffer width and effectiveness mainly in terms of the following functions:

- Sediment removal and erosion control
- Dissolved pollutant removal
- Large woody debris (LWD) recruitment

- Water temperature moderation
- Wildlife habitat and corridors

Sediment and pollutant trapping functions are sometimes known as “sink” functions, as they remove unwanted elements from the environment (Castelle and Johnson, 2000). The functions that provide essential elements to the environment are sometimes known as “source” functions (Castelle and Johnson, 2000). For example, trees growing in buffers can provide large woody debris to wetlands; LWD can be an important wildlife habitat component. Literature summarized here addresses both sink and source functions. Not that most studies of sink functions occurred in agricultural areas while most source function studies occurred in silvicultural settings. Few studies have been conducted in highly urbanized areas. Therefore, care must be taken in applying research conducted under one set of conditions to another.

The literature shows that the buffer widths needed to be effective for these functions varied considerably; thus, the literature is not definitive in identifying an ideal buffer width for each function studied. However, certain trends are apparent. For sink functions, significant protection can be achieved with buffers ranging from 25 to 100 feet in width. A similar range of buffer widths was also shown to be effective for source functions, although for some specific wildlife species, effective buffer widths can range up to several hundreds of feet.

Not surprisingly, under a given set of conditions, wider buffers offer greater amounts of protection. However, the relationship between buffer width and effectiveness is logarithmic, so that incremental increases in buffer width provide a decreasing amount of extra protection. This logarithmic relationship can best be explained mathematically by considering the filtering functions of buffers. Each buffer has a certain capacity for removing material passing through it. Further, filtered material can be thought of as being retained within the buffer. The relationship between Rp, the amount of material retained by a buffer, and t, the rate of material transmittal (called the transmissivity) through a unit buffer of width w, can be explained by the following equation (Wellet et al., 1998):

$$Rp = (1-tw)$$

Therefore, low t values indicated buffers that inherently allow little material to pass through, or transmit material slowly; as a result, these buffers retain a high amount of material. The “material” retained that is denoted by Rp may be virtually any substance: sediment, chemicals in surface or groundwater, light, noise, domestic animals, etc. As an example, consider shining a laser pointer through a sheet of white paper; most of the light is transmitted through the paper because white paper has a high t value, or high transmissivity. It may require a dozen or more sheets of white paper to completely filter out the light. Now consider shining the same light through a piece of black paper of the same thickness as the white; little if any light penetrates the paper because the transmissivity of the black paper is low, that is, it has a low t value. In this example, the white paper represents a poor-quality buffer and black paper represents a high-quality buffer. The thickness of the poor-quality buffer had to be many times that of the high-quality buffer in order to achieve the same level of performance. Unfortunately, the importance of buffer quality has gotten little attention by most agencies; even the Department of Ecology's 1990 Model Wetlands Protection Ordinance focuses only on wetland rating and the "intensity" of the adjacent land use in establishing buffer requirements.

However, the Washington Department of Ecology published a two volume set of documents called Wetlands in Washington State. Volume 1 of this set is entitled "A Synthesis of Science" and has a discussion on wetland buffers. As stated above, effectiveness of wetland buffer width depends on what functions they are protecting. For example, the literature on effectiveness of buffer widths suggest buffers between 25 and 75 feet for wetlands with minimal wildlife habitat functions and adjacent low-intensity land uses; and 150-300 feet for wetland with high habitat functions. Effective buffer widths for protecting water quality ranged from 25 to 50 feet for 60% removal of pollutants, to 150-200 feet for 80% removal of pollutants.

II.2.2 Wetlands Characterization

This characterization of wetlands in the City of Lake Stevens is based on a combination of review of various wetland reports on file at the City, a field visit in 2005 and a second one in December 2006, and on a review of wetland inventory information assembled by the City (City of Lake Stevens 2007). It is also based on the information in several publications of the Washington State Department of Ecology. The Washington State Wetland Rating System for Western Washington – Revised (Ecology 2004) provided the basis for the ratings used and also provided a basis for understanding and characterizing various wetland functions. Further guidance was taken from "Wetland Mitigation in Washington State, Parts 1 and 2" (Ecology et al 2006), which are joint publications of the Department of Ecology, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency, Region 10.

The City of Lake Stevens is highly urbanized and does not contain large tracts of connected wetland area. The majority of wetlands within the City boundaries have been identified on the eastern edge of the City limits and along Lundeen and Stevens Creeks in the northwestern portion of the City. Many of these wetlands have been identified as part of the construction permit process during the last 15 years. The western portion of the City, north of the lake, has the largest concentration of development and very few wetland areas. The central portion of the City also is located on a slope, which does not typically favor wetland conditions.

Lake Stevens contains palustrine forested (PFO), scrub-shrub (PSS), and emergent (PEM) wetlands. There are not many lacustrine (lake fringe) wetlands in City, as most of the lakeshore is armored. A large number of the wetlands appear to be forested and surrounded by residential developments. Forested wetlands in Lake Stevens are typically dominated by western redcedar (*Thuja plicata*), red alder (*Alnus rubra*), and/or black cottonwood (*Populus balsamifera*). Common dominant species in scrub-shrub wetlands include salmonberry (*Rubus spectabilis*), hardhack (*Spiraea douglasii*), and willows (*Salix* spp.). Common dominant species in emergent wetlands include reed canarygrass (*Phalaris arundinacea)*, cattails (*Typha latifolia*), creeping buttercup (*Ranunculus repens*), and small-fruited bulrush (*Scirpus microcarpus*).

Some of the wetlands in Lake Stevens are associated with the major drainages: Stevens, Stevens/Catherine, Catherine and Lundeen Creeks. These wetlands can be narrow bands on either side of the stream channel like those adjacent to Stevens Creek or broader floodplain areas along some stretches of Catherine or Stevens/Catherine Creek. These wetlands often have a large component of non-native and/or noxious weeds including purple loosestrife (*Lythrum salicaria*), reed canarygrass, and Bohemian knotweed (*Polygonum bohemicum*).

Currently there are two Category I wetlands identified within the City of Lake Stevens (City of Lake Stevens 2007). Category II and III wetlands are the most common wetland classifications, with only a few Category IV wetlands currently identified.

II.3 Threatened and Endangered Species

Bull trout (federally listed as threatened under the ESA) occur as a reproducing population in the Skykomish River subbasin of the Snohomish River basin. This subpopulation of Puget Sound bull trout is considered healthy by the Washington Department of Fish and Wildlife (WDFW). The Stevens/Catherine Creek basin drains into the Little Pilchuck River, which is a tributary of the Pilchuck River (a subbasin of the lower Snohomish River basin. Although bull trout reproduction does not occur in the Pilchuck River subbasin, the Pilchuck River is considered core overwintering, foraging, and refuge critical habitat for bull trout by the US Fish and Wildlife Service. Although foraging bull trout may occasionally enter Stevens/Catherine Creek during the fall months, they have not been documented in the Stevens/Catherine Creek subbasin and the subbasin is not considered critical habitat for bull trout.

The nearest known occurrence of Chinook salmon (federally listed as threatened under the ESA) is the Pilchuck River. The Pilchuck River is both spawning and rearing habitat for Snohomish fall-run Chinook salmon, which is considered depressed by the WDFW. Although Chinook salmon do not occur in the Stevens/Catherine Creek subbasin, all anadromous reaches of the Snohomish River system were originally designated as critical habitat for Chinook salmon under the ESA. This designation has been removed by NOAA fisheries during a recent 2 year review, but may eventually be proposed again at the end of the review period. A designation of anadromous reaches of the subbasin as critical habitat for Chinook salmon may require adjustments of riparian buffers, depending upon criteria yet to be determined by NOAA fisheries. At a minimum, it should be expected that buffers should protect water quality for downstream reaches in the watershed that contain populations of Chinook salmon. ESA critical habitat buffers are a separate issue from protective standards mandated by the Growth Management Act.

Puget Sound steelhead trout (federally proposed for listing as threatened under the ESA) that have migrated through Stevens/Catherine Creek and the outlet reach of Stevens Creek have been observed in Lake Stevens (likely spawning in either the portion of upper Stevens Creek that drains into Lake Stevens or in nearby Lundeen Creek) and may occasionally enter Catherine Creek.

Puget Sound-Strait of Georgia coho salmon (a federal ESU species of concern under the ESA) currently spawn in all accessible streams within the Stevens/Catherine Creek basin. These coho salmon are part of the Snohomish River stock and the run is considered depressed by the WDFW.

The closest bald eagle (*Haliaeetus leucocephalus*), no longer federally listed as threatened under the ESA, nesting territories are on the north shore of Lake Stevens about 2 miles from the streams within the city limits. The two pair of resident bald eagles forage in Lake Stevens and the Snohomish River estuary. Bald eagles are observed in winter in low numbers and occasional over flights may occur in the vicinity of stream channels, but no known roosts are present. Streams within the city limits are too small for easy access to foraging bald eagles and do not contain large concentrations of spawning chum salmon or waterfowl concentration, which are the preferred forage. Bald eagles in the Lake Stevens vicinity perch along the north shore and forage on populations of fish and waterfowl in the lake. Spawning kokanee in Kokanee Creek are generally unavailable due to the urban nature of the creek basin and the small size of the stream. Bald eagles have been delisted by the US Fish and Wildlife Service.

III. BAS REVIEW

Revisions to the draft Lake Stevens Code occurred in 2007. The code chapters govern the definition of and activities in Streams, Creeks, Rivers, Lakes, and Other Surface Waters, in light of the Best Available Science (BAS) guidelines expressed in the Washington Administrative Code (WAC). BAS review comments on earlier drafts of the code have been incorporated into the current draft code, and code elements now appear to meet BAS guidelines.

III.1 Lake Stevens Code: Streams, Creeks, Rivers, Lakes, and Other Surface Waters

The 2007 draft Lake Stevens Code was reviewed to identify which elements are based on BAS specific to the region. Annotated references for the BAS for these elements are found in the bibliography. In addition, a response to State Department of Ecology comments on earlier versions of the draft City Code and the BAS is included in Appendix C.

This evaluation is limited to physical and biological sciences and does not include engineering- or design-based specifications. In addition, code sections or provisions that are substantially based on the regulatory requirements of existing state, federal, or other management programs are also not examined with the understanding that these regulations are based on or require the use of BAS.

IV. ANNOTATED BIBLIOGRAPHY

Barling, R.D, and I.D. Moore. 1994. Role of Buffer Strips in Management of Waterway Pollution: A Review. *Environ. Management* 18:543-558.

Methods for modeling buffer strips performance as functions for improving channel stability, acting as filters for sediment and nutrients, water purification, impact as a non-disturbance area, and roles as terrestrial and stream habitat are reviewed with specific application to Australian conditions and methods for modeling.

Barton, D.R., W.D. Taylor, and R.M. Biette. 1985. Dimensions of Riparian Buffer Strips Required to Maintain Trout Habitat in Southern Ontario Streams. *North American Journal of Fisheries Management* 5:364-378.

This article compared the presence of trout in southern Ontario streams and daily maximum temperatures with buffer strip widths. Streams with weekly maximum temperatures less than 72°F had robust trout populations, while streams with maximum temperatures over 72°F either had no trout or small populations of trout. Buffers rarely are centered on stream, thus effective buffer strip width is actually less than estimated in most studies. Studies in Oregon indicate that buffer strips only need to be wide enough to include trees contributing to canopy cover. A 33 feet wide strip was found to be adequate for shade. Since blockage of direct insolation by foliage is of primary importance, buffers of narrow streams may be less than 33 feet and dense shrubs can provide riparian shade for smaller streams. Unshaded streams reached their maximum temperature earlier in day than shaded stream, but had similar minimum temperatures at night. A weekly maximum temperature of 72°F corresponded to an overall maximum of 78°F, very close to the short-term lethal temperature for most salmonids.

Beechie, T.J. and T.H. Sibley. 1997. Relationships Between Channel Characteristics, Woody Debris, and Fish Habitat in Northwestern Washington Streams. *Trans. Am. Fish. Soc.* 126:217-229

This article analyzes the relationships between LWD and pool area or pool spacing varied with channel slope and channel width for streams in second-growth forests. The influence of LWD on pool formation changes with channel slope. Analysis of pool-forming mechanisms indicates that low-slope channels are less sensitive to LWD abundance because pools are formed by mechanisms other than LWD when LWD abundance is low. The size of LWD that forms pools increases with increasing channel width, but is not related to channel slope. The percent gravel is best explained by channel slope and channel width, with no relationship between LWD and percent gravel (explained by a channels capacity to transport particles of various sizes.)

Belt, G.H., J. O'Laughlin and T. Merrill. 1992. Design of Forest Riparian Buffer Strips for the Protection of Water Quality: Analysis of Scientific Literature. Idaho Forest, Wildlife and Range Policy Analysis Group Rept. No. 8. Univ. of Idaho, Moscow, Idaho.

This document summarizes the findings of previous studies relating to riparian buffer strips and their relationship to forest practices, water quality, and fish habitat. The article

also includes quantitative data derived from existing studies that had previously examined buffer widths and their functions related to different parameters including stream temperature and large organic debris (LOD). Models predicting the effectiveness of buffer strips are briefly described.

Berge, H.B. and K. Higgins. 2003. The Current Status of Kokanee in the Greater Lake Washington Watershed. King County Department of Natural Resources and Parks, Water and Land Resources Division. Seattle, Washington.

This paper details the status of kokanee stocks in the Lake Washington-Lake Sammamish watershed. It is surmised that Lake Stevens kokanee originally were transplanted into Lake Stevens in 1912 or 1913 from Bear Creek. This conclusion is due to similar spawn timing, size at maturity, and fecundity. At that time of the transplant, most transplants were from nearby sources, due to primitive fish handling/hauling abilities. Lake Stevens kokanee also closely match Lake Sammamish late-run kokanee in most respects. No genetic analysis has been done on Lake Stevens kokanee.

Beschtal, R.L. 1997. Riparian Shade and Stream Temperature: An Alternative Perspective. *Rangelands* 19:25-28

The author reviews the effects of riparian shade on stream temperatures. The author concludes that although shade from tree canopy can be used to intercept heat input to a stream through direct solar radiation over water, in reality this interception will yield only limited benefits in many situations. Shade duration and quality is influenced by vegetation height, density of canopy, and vegetation shade angle. Shade from ravines is also a factor, as is microclimate in ravines that reduces conduction between streambed and water. Shrubs are important sources of shade for intermediate sized streams and herbaceous plants, such as sedges and rushes can significantly contribute to overall levels of shading for small meadow streams. Energy exchanges may involve solar radiation, longwave radiation, evaporative heat transfer, convective heat transfer, conduction, and advection. Longwave losses and gains essentially balance each other, leaving solar radiation as the primary radiant energy source for heating streams.

Bolton, S. and J. Shellberg. 2001. Ecological Issues in Floodplains and Riparian Corridors. Prepared by the University of Washington Center for Streamside Studies, Seattle, Washington.

This document presents an overview and assessment of the state of knowledge of ecological issues in floodplains and riparian corridors. Studies of forest stream buffers suggest that buffers need to be between 328 to 656 feet wide in order to limit negative population effects such as nest predation due to edge effects. This assumes that forest birds will use riparian buffers and that bird use is correlated to buffer width, neither of which has been shown. A study of the effects of riparian areas around small streams indicated no discernible effect of bird diversity by the riparian stand. Riparian habitat along small streams is usually insufficient to support large animals. Recent studies have shown that small mammal populations numbers are not adversely affected by current riparian buffer sizes, at least in the short term.

Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, Marit G. Larson, P.C. Henshaw, E.J. Nelson, S.J. Burges. 2001. Urban Stream Rehabilitation in the Pacific Northwest. University of Washington. Center for Water and Watershed Studies, Seattle, Washington.

This document summarizes effects of different rehabilitation treatments, including riparian buffers, on stream functions. It finds that summertime stream temperatures are only modestly influenced by watershed urbanization, but are most directly influenced by changes to the riparian canopy and to a lesser extent by flow conditions. The warmest condition (full sun on stagnant water) may not be the most biologically significant, because even though it reduces the length of suitable summertime habitat for cold-water fish it does not represent a major thermal input of hot water into potentially cooler reaches farther downstream. Summertime baseflow generates stream temperatures, which are influenced primarily by groundwater temperatures, with no significant influence of surrounding urbanization. It also states that urbanized land uses have only modest sediment yields, particularly where steep slopes do not exist to contribute to a high landslide rate and efficient sediment delivery to stream channels.

Boyd, M. and D. Sturdevant. 1996. The Scientific Basis for Oregon's Stream Temperature Standard: Common Questions and Straight Answers. Oregon Department of Environmental Quality, Salem, Oregon.

This document presents the scientific basis for Oregon's stream temperature standards. The document concludes that a 65°F criterion in stream temperature is appropriate for general salmon and trout use. This is 7-day moving average of the daily maximum temperatures (7 warmest consecutive days during a year). A separate criteria of 55°F (spawning, egg incubation, and fly emergence) was determined for spawning periods. The standard is based on sub-lethal effects not the directly lethal temperatures, which begin at approximately 70°F. Sub-lethal effects were determined to begin at stream temperatures of 64°F and above. Optimal juvenile growth rates for coho occur at temperatures below 60°F. A 7-day maximum moving average of 64°F is above the optimal temperature for rearing, but only occurs for part of the day during a few of the warmest week of summer, reducing risk to a minimal level. Direct solar radiation was determined to be the primary source of heat energy in streams. Temperature effects increase as flow decreases, with only small effects at higher flows. Streams with low flow volumes were found to be extremely temperature sensitive. Convection between the stream surface and air is very limited as a source of heat or heat loss. Evaporation is primarily a factor in small streams. Streambed conduction (both heat source and heat loss) can be important in smaller streams and low flow rates, with the effect more pronounced over bedrock. Groundwater inflow/outflow was found to have a cooling influence and was determined to be the primary reason streams lose water temperatures in shaded stream reaches. Stream heating from solar radiation was considered rapid, while processes for dissipating heat energy were slow.

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This publication describes a wetland classification system that is used to separate different wetland types for the purpose of assessing their functions. Wetlands are grouped into different categories based on their geomorphic setting, their water source, and differences in the fluctuations of water levels.

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An annotated bibliography that is a companion document to the previous reference. It contains many references not summarized in the prior document.

Castelle, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, T. Erickson, and S.S. Cooke. 1992. Wetland Buffers: Use and Effectiveness. Publication # 92-10. Adolfson Assoc., for Shorelands and Coastal Zone Manage. Program, Washington Dept. of Ecology, Olympia, WA.

A Best Available Science review from the early 1990s. Includes literature reviews of many buffer functions, primarily discussing effectiveness as a function of buffer width. It also contains a nationwide survey of buffer requirements from dozens of agencies throughout the U.S.

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This paper presents discussions of buffer effectiveness as it relates to buffer width for six buffer functions.

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This publication provides quantitative data on riparian and grass filter strip effectiveness of sediment and chemical removal from agricultural fields in North Carolina. Both types of filters retained 50 to 80% of sediment and 20 to 50% of the chemicals studied which included phosphorus, phosphate, ammonium, Kjeldahl nitrogen, and nitrate.

Desbonnet, A., P. Pogue, V. Lee, and N. Wolff. 1994. Vegetated Buffers in the Coastal Zone. Coastal Resources Center, Rhode Island Sea Grant, Univ. of Rhode Island.

This report summarizes the scientific literature up to 1994 on the effectiveness of different buffer widths at maintaining the functions of aquatic resources. It also summarizes the functions provided by different buffer widths.

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This document contains information concerning stream/riparian habitat and historic and current fish usage of streams in the Lake Stevens/Catherine Creek watershed.

Elmore, W., and R.L. Beschta. 1987. Riparian Areas: Perceptions in Management. *Rangelands* 9:260-265.

The authors of this paper aim to promote awareness of riparian issues, identify characteristics and benefits of productive riparian systems, and encourage public and private landowners to reconsider the effects of traditional grazing practices.

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Landmark publication is the combined effort of dozens of researchers and forest management practitioners. Prepared in response to President Clinton's directive to find ways to break the gridlock over federal forest management.

Fennessy, M.S., and J.K. Cronk. 1997. The Effectiveness and Restoration Potential of Riparian Ecotones for the Management of Nonpoint Source Pollution, Particularly Nitrate. *Critical Reviews in Environmental Science and Technology* 27:285-317.

This paper summarizes literature documenting water quality benefits of riparian buffer strips. A general discussion includes the following topics: the denitrification in buffer vegetation; mechanisms by which nitrogen, phosphorus, and solids are removed from agricultural runoff; parameters influencing surface retention of nutrients and sediment; and buffer subsurface retention.

Flanagan, D.C., G.R. Foster, W.H. Neibling, and J.P. Burt. 1989. Simplified Equations for Filter Strip Design. *Trans. of the ASAE.* 32:2001-2007.

This study incorporates the CREAMS model (USDA, 1980) to predict sediment delivery through filter strips in conditions of shallow, overland flow. Equations provided by the

CREAMS model can be used to select the minimum width of filter strips required to trap a desired level of sediment when the strip is composed of dense grass and is located at the base of a slope having minimal flow concentrations.

Granger, T., T. Hruby, A. McMillan, D. Peters, J. Rubey, D. Sheldon, S. Stanley, E. Stockdale. April 2005. Wetlands in Washington State – Volume 2: Guidance for Protecting and Managing Wetlands. Washington State Department of Ecology. Publication #05-06-008. Olympia, WA.

This document contains draft guidance for local governments on managing and protecting wetlands and their functions based on the synthesis of the science in Volume 1. Themes and messages include: relying on a site-by site approach to managing wetlands fails to effectively protect them; effective protection of wetlands and their functions must include management of their interaction with the environmental factors that control wetland functions; information generated through landscape analysis is needed and should be used in developing measures to manage and protect wetlands and their functions; and protections and management measures should incorporate comprehensive plans subarea plans, green infrastructure plans, regulations such as critical areas ordinances, clearing and grading ordinances, and non-regulatory programs to restore and preserve using voluntary efforts and incentives.

Haberstock, A.E., J.G. Nichols, M.P. DesMeules, J. Wright, J.M. Christensen, and D.H. Hudnut. 2000. Method to Identify Effective Riparian Buffer Widths for Atlantic Salmon Habitat Protection. *J. Am. Wat. Res. Assoc*. 36:1271-1286.

This paper summarizes a method developed in 1999 to determine effective riparian buffer widths for Atlantic salmon habitat protection as part of the Atlantic Salmon Conservation Plan for seven Maine Rivers. A predictive model that serves as a basis for the method suggests riparian buffer widths should be based on measurable buffer characteristics that affect buffer function such as slope, soil characteristics, and plant community structure and density.

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This document contains information about stream and fisheries resources in the Lake Stevens, Stevens Creek, and Catherine Creek basin.

Herson-Jones, L.M., M. Heraty and B. Jordan. 1995. Riparian Buffer Strategies for Urban Watersheds. Metropolitan Washington Council of Governments, Publ. No. 95703, Washington, D.C.

This document provides guidance on riparian buffer programs used to mitigate the impact of urban areas on nearby streams. The paper utilizes the results of a national survey of riparian buffer programs, as well as a comprehensive review of riparian buffer literature to make recommendations on buffer design. Buffer pollutant removal potential and pollution prevention techniques via chemical, biological, and physical processes are also analyzed.

Hetrick, N.J., M.A. Brusven, T.C. Bjornn, R.M. Keith, and W.R. Meehan. 1998. Effects of Canopy Removal on Invertebrates and Diet of Juvenile Coho Salmon in a Small Stream in Southeast Alaska. *Trans. Am. Fish. Soc.:* Vol. 127: 876-888.

This paper addresses the issues of riparian vegetation management strategies. Water temperatures changed little when flows are high, but with low flows, stream temperatures can exceed optimal growth temperatures for coho within 66 feet for clear sunny days and 164 feet for cloudy and overcast days.

Hetrick, N.J., M.A. Brusven, W.R. Meehan, and T.C. Bjornn. 1998. Changes in Solar Input, water Temperature, Periphyton Accumulation, and Allochthonous Input and Storage after Canopy Removal along Two Small Salmon Streams in Southeast Alaska. *Trans. Am. Fish. Soc.* 127:859-875.

This paper addresses the issues of riparian vegetation management strategies. The authors measured changes in the variables in small streams in Alaska. Allochthonous input decreased after canopy removal, but the amount of organic material stored in substrate did not change. Water temperatures changed little during high flows, but during low flows, stream temperatures could exceed optimal growth temperatures for coho salmon within 66 feet for clear sunny days and 164 feet for cloudy and overcast days.

Jagt, K. 2004. Kokanee Creek Restoration Ten-year Assessment. Seattle University Department of Civil and Environmental Engineering, Seattle, Washington.

This paper contains information about the baseline conditions and fish utilization of Kokanee Creek in the City of Lake Stevens, Washington.

Johnson, A.W., and D. Ryba. 1992. A Literature Review of Recommended Buffer Widths to Maintain Various Functions of Stream Riparian Areas. King County Surface Water Management Division, Seattle, WA.

This paper examines existing scientific literature on the function of riparian areas along streams, specifically those documents containing recommendations for buffer widths to maintain those functions, and various methodologies for setting buffer widths. Varying buffer widths are suggested based on the reviewed literature.

Jones & Stokes Associates, Inc. (J&S). 1994. Lake Stevens Woods Proposed Residential Development, Lake Stevens, Washington. Fisheries Report. January 27. Prepared for Shockey/Brent, Inc., Everett, Washington by Jones & Stokes Assoicates, Inc., Bellevue, Washington.

This report includes the results of surveys of Catherine Creek and its tributaries (including Springbrook Creek for the Lake Stevens Woods Development bounded by 36th Street on the north, 30th Street on the south, Grade Road on the west, and 127th Avenue on the east.

Keith, R.M., T.C. Bjornn, W.R. Meehan, N.J. Hetrick, and M.A. Brusven. 1998. Response of Juvenile Salmonids to Riparian and Instream Cover Modifications in Small Streams Flowing through Second-Growth Forests of Southeast Alaska. *Transactions of the American Fisheries Society* 127:889-907.

This article compared the effects of different riparian buffer widths and lengths on small southeast Alaskan coho salmon streams. Temperatures in clear-cuts increased by an average of 5-7°F within a distance of 174 feet. The maximum temperature increase was 11°F.

Kinley, T.A. and N.J. Newhouse. 1997. Relationship of Riparian Reserve Zone Width to Bird Density and Diversity in Southeastern British Columbia.

This article compares the effects of riparian buffer widths in British Columbia and Montana on bird density and diversity. Prescribed riparian management areas near permanent streams under current guidelines (99 feet) had lower densities of total birds and of riparian-associated birds than if reserves were required to average 230 feet in width. The density of all birds combined, all riparian-associated birds combined, and three of the four riparian-associated species increased with increasing reserve zone width (46, 121, and 230 feet wide). Species diversity and species equitability did not differ significantly among treatments.

Kusler, J.A., and M.E. Kentula (eds.). 1990. *Wetland Creation and Restoration: The Status of the Science.* Island Press, Washington, D.C. and Covelo, California.

A collection of papers from many authors, primarily from the U.S., providing an early 1990s "bible" for creating and restoring wetlands. Also includes papers on establishing mitigation ratios, developing monitoring, and how to obtain critical data.

Lassettre, N.S. 1999. Annotated Bibliography on the Ecology, Management, and Physical Effects of Large Woody Debris (LWD) in Stream Ecosystems.

This paper summarized articles and documents concerning LWD in stream ecosystems.

Leavitt, J. 1998. The Functions of Riparian Buffers in Urban Watersheds. University of Washington, Department of Civil Engineering, Seattle, Washington.

The author reviews the literature concerning the functions of riparian buffers in urban watersheds. The author addresses the unique characteristics of urban watersheds and the effects these have on riparian functions. The expectations of full restoration of stream function is largely a consequence of having a majority of buffer studies being done in forested and agricultural watersheds, both of which have characteristics distinctly different from those of urban watersheds. In addition, most studies have been very site specific and conclusions reached are not necessarily applicable when applied elsewhere. The paper concludes that one of the most basic functions of riparian buffers in urban watersheds is to reduce the direct encroachment of humans on stream banks. Intact riparian buffers and exclusion of banks from encroachment by humans decreases bank erosion, dumping of refuse, visual degradation, and sensitive fish and wildlife species from visual disturbances caused by human activities. The document lists two categories of hydrological functions served by riparian buffers, functions that influence hydrology even if the buffer is partial and functions that are not provided if a buffer is partial (because the buffer is bypassed by channelized flow). Functions in the first category includes the reduction of water reaching stream channels due to evapotranspiration and the slow release of stormwater through infiltration; increased roughness of channels above bank full depth slowing peak flows and increasing storage and infiltration; dissipation of additional water before it enters the channel; and the role of LWD and leaf fall as sources of organic inputs, increasing storage of sediment, reducing the rate of sediment transport; and the development of channel complexity. Functions in the second category include increased number of channelized stormwater inputs by-passing buffers, reducing the ability of buffers to reduce peak flows, leading to the degradation of channels from greater frequency and magnitude of high flows. Riparian buffers were also found to influence water quality by providing shade (preventing water temperature increase from solar radiation), and intercepting nutrients, pollutants, and sediment from stormwater runoff. Vegetation serves as a sink for dissolved nutrients and a source of complex organic material (leaf fall). Forested buffers can remove 65% of the nitrogen and 30% of the phosphorus from surface and groundwater. Riparian vegetation also was found to create a microclimate that moderates stream temperature, decreasing solar heating in the summer and trapping back-radiation in the winter. The paper found that it is difficult to avoid channelization in urban environments, creating streams that are less stable, with flashier, higher flows and less diverse assemblages of benthic macroinveterbrates. Although riparian buffer widths of over 50 feet were considered excellent, 10 to 50 feet of riparian buffer was found to provide most of the functions possible under urban environmental conditions. Finally, the paper stated that the protection of riparian buffers alone is not adequate to ensure stream channels will not be degraded. Changes in hydrology and

Lee, K., T.M. Isenhart, R.C. Schultz, and S.K. Mickelson. 2000. Multispecies Riparian Buffers Trap Sediment and Nutrients during Rainfall Simulation. *J. Environ. Qual.* 29:1200-1205.

The study in this article provided quantitative data for the effectiveness of multispecies riparian buffers (MRBs) and their removal of sediment, nitrogen, and phosphorus from cropland runoff. Switchgrass (Panicum virgatum L.) and a combination switchgrass-woody plant buffer were determined to be effective in the removal of sediment and chemicals.

Lienkaemper, G.W. and F.J. Swanson. 1987. Dynamics of Large Woody Debris in Streams in Old-Growth Douglas-Fir Forests. *Canadian Journal of Forest Resources* 17:150-156.

The authors studied the dynamics of LWD in streams in old-growth Douglas-fir forests. Wind was found to be the LWD delivery agent in 69% of cases, with bank cutting the delivery agent 31% of the time. Trees growing in stream banks were particularly prone to falling into stream channel, even without bankcutting, due to the asymmentry of the rooting environment in proximity to a stream channel and the tilt of trees growing into the open canopy space above a channel.

Lynch, J.A., G.B. Rishel, and E.S. Corbett. 1984. Thermal Alternation of Streams Draining Clearcut Watersheds: Quantification and Biological Implications. *Hydrobiologia* 111:161-169

The authors elaborate upon an earlier published study of three watersheds in Central Pennsylvania that experienced differing levels of timber harvesting activity. Maximum stream temperatures averaged 2°F higher in commercial clearcuts, and 16°F higher in clearcut-herbicide watersheds. Clearcuts had 99 feet of riparian buffer.

Machtans, C.S., M. Villard, and S.J. Hannon. 1996. Use of Riparian Buffer Strips as Movement Corridors by Forest Birds. *Conservation Biology* 10:1366-1379.

The purpose of this three-year study was to determine whether songbirds use riparian buffer strips of forest connecting forest reserves as corridors and if these corridors are used more frequently than clearcut land crossings. Results concluded riparian corridors were used more frequently than clearcuts by forest bird species and movements of some bird species represented an instinctive dispersal through corridors.

Marble, A.D. 1992. *A Guide to Wetland Functional Design.* Lewis Publishers, Boca Raton, Florida.

A textbook providing guidance on creating or increasing wetland functions. It is based on the Wetland Evaluation Technique, which is used to determine relative values of wetland function. Site selection and design criteria are discussed for numerous functions.

Marble, A.D. 1992. *A Guide to Wetland Functional Design.* Lewis Publishers, Boca Raton, Florida.

A textbook providing guidance on creating or increasing wetland functions. It is based on the Wetland Evaluation Technique, which is used to determine relative values of wetland function. Site selection and design criteria are discussed for numerous functions.

Marczin, P. 1999. Lake Stevens Bridge Replacement Bridge 125, Biological Assessment. Prepared by Public Involvement/Environmental Group, Snohomish County Department of Public Works for Snohomish County Department of Public Works, Everett, Washington.

This BA documents the environmental baseline of Catherine Creek in the vicinity of a bridge replacement project.

McDade, M.H., F.J. Swanson, W.A. McKee, J.F. Franklin, and J. Van Sickle. 1990. Source Distances for Coarse Woody Debris entering Small Streams in Western Oregon and Washington. *Can. J. For. Res*. 20:326-330.

The objective of this study was to determine the source distance patterns of coarse woody debris in selected streams flowing through natural conifer forests. Several stand and landform conditions were studied including varying stream channel size, side-slope steepness, and the age of the surrounding forest. Results from this study can be used to interpret the effects of buffer strips of various widths on future amounts of woody debris entering streams.

McDade, M.H., F.J. Swanson., W.A. Mckee, J.F. Franklin, and J. Van Sickle. 1990. Source Distances for Coarse Woody Debris Entering Small Streams in Western Oregon and Washington. *Canadian Journal of Forest Resources* 20:326-330.

The authors collected data on at least 30 fallen trees at each study site on 39 streams in Oregon and Washington. The distribution of distances from rooting site to bank was

similar among streams, with 11% of the total number of debris pieces originating within 3 feet of the channel and over 70% originating within 65 feet. Stands with taller trees (old-growth conifers) contributed coarse woody debris to streams from greater distances than trees from younger stands.

Meehan, W.R. 1996. Influence of Riparian Canopy on Macroinvertebrate Composition and Food Habits of Juvenile Salmonids in Several Oregon Streams. Research Paper PNW-RP-496, US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Although coastal cutthroat diet and vertebrates present vary significantly between canopied and noncanopied streams, in terms of the amount of preferred fish food organisms available, the presence or absence of riparian canopy does not seem to be of any practical importance in terms of the amount of preferred food available to the fish.

Mitsch, W.J., and J.G. Gosselink. 2000. *Wetlands*. 3rd ed. Van Nostrand Reinhold, New York.

This is the basic textbook on wetlands used by many colleges and universities. It provides a good summary of the chemistry, geology, hydrology, and biology of wetlands.

Moore, R. 2001. Do Clearcut-heated Streams Cool When They Flow Back into the Forest? *Branch Lines* 12:3

The author analyzed data from stream temperatures monitored in three small streams in central interior British Columbia. Streams were found to cool markedly in less than 656 feet of channel after flowing back into forested habitat. Inflow of cool groundwater, bed heat conduction and hyporheic exchange were considered as causes of stream cooling. The greatest “cooling” was found to usually occur during dry periods and low flows. It was concluded that one stream lost warm water by bed infiltration in the upper part of the “cooling reach,” then gained cold groundwater just upstream of the lower temperature logger. It was inferred that in observed cooling downstream of forestry activity is due to water heated by solar radiation being lost and replaced by cold groundwater, suggesting that harvesting of headwater streams may have little effect on temperatures in downstream reaches. However, the process controlling the cooling of the study streams may be site specific. Replication of the study in other geographic contexts was suggested.

Morley, S.A. 2000. University of Washington, School of Fisheries, Seattle, Washington.

The study consisted of an analysis of benthic macroinvertebrate indices of biotic integrity (B-IBI) variability relative to land cover changes, evaluation of the diagnostic properties of B-IBI, and an assessment of biological response associated with stream restoration projects.

Mueller, K.W. 1997. Lake Stevens Survey: The Warmwater Fish Community after Implementation of a Minimum Length limit on Largemouth and Smallmouth Bass. Washington Department of Fish and Wildlife, LaConner, Washington.

This document contains information about the fish present in streams draining into and out of Lake Stevens.

Murphy, M.L. and K.V. Koski. 1989. Input and Depletion of Woody Debris in Alaska Streams and Implications for Streamside Management. *North American Journal of Fisheries Management* 9:427-436.

The authors studied natural rates of input and depletion of LWD in southeast Alaska streams. Nearly all LWD was derived from within 99 feet of stream banks

National Research Council. 1996. Guidelines for the Development of Wetland Replacement Areas. Transportation Research Board. NCHRP Report 379.

This publication is a comprehensive review of wetland mitigation. It covers function assessment, setting goals and objectives, site selection, site design and construction, and developing conceptual and final mitigation plan. The appendices cover specific wetland elements (hydrology, soils, vegetation, and cost estimating) in more detail.

National Wetlands Inventory. 1986. Fish and Wildlife Service, U.S. Dept. of the Interior, Washington, D.C.

A series of maps, based on air photos superimposed on U.S.G.S. quadrangles, depicting potential wetland locations based on air photo interpretation. Maps also include wetland classifications based on Cowardin et al. (1979).

Natural Resources Conservation Service. 1997. Riparian Forest Buffer. USDA NRCS Conservation Practice Job Sheet No. 391.

This guide from the NRCS defines the purpose of riparian forest buffers and notes features of the natural environment that provide an effective streamside buffer. A "Riparian Forest Buffer – Specifications Sheet", a site-specific worksheet that lists what type of forest buffer would be required in accordance with the NRCS Filed Office Technical Guide, is included in the guide.

Nelson, E. 2001. Sediment Budget of a Mixed-Use, Urbanizing Watershed. University of Washington. Center for Water and Watershed Studies, Seattle, Washington.

The author studied sediment budgets in urban and urbanizing areas in relation to land use and land cover. Urban roads and urban residential development was found to be a relatively minor source of sediments.

Pfeifer, R.L. 1978. Evaluation of the Natural Reproduction of Kokanee (Oncorhynchus nerka Walbaum) in Lake Stevens, Washington, as Related to the Lake Limnology and Basin. Masters Thesis, University of Washington, School of Fisheries, Seattle, Washington.

This document documents the life history and distribution of kokanee salmon in the Lake Stevens watershed.

Quinn, J., A. Taylor, W. Boyce, and T. Fenton. 2000. Riparian Zone Classification Improves Management of Stream Water Quality and Aquatic Ecosystems. *In*: P.J. Wigington and R.L. Beschta (eds.), 2000. Riparian Ecology and Management in Multi-Land Use Watersheds. American Water Resources Association, Middleburg, VA, TPW-00-2, 616 pp.

This paper emphasizes that not all buffer functions are of equal importance to different aquatic systems, including wetlands in various landscape settings.

R2 Resource Consultants, Inc. (R2). 2000. Historic and Current Status of Kokanee in the Lake Washington Basin. Prepared by R2 Resource Consultants, Redment, Washington for the King County Department of Natural Resources, Seattle, Washington.

This document contains information about the kokanee salmon present in Lake Stevens and spawning in Kokanee Creek.

Richardson, J.L., and M.J. Vepraskas (eds.). 2001. *Wetland Soils: Genesis, Hydrology, Landscapes, and Classification.* Lewis Publishers, Boca Raton, Florida.

This new book is one of a very few written entirely about wetland soils. As the title suggests, it covers how and where wetland soils form, but also contains a classification scheme for wetland soils. The book contains data and examples from throughout the U.S.

Robison, G.E. and R.L. Beschta. 1990. Identifying Trees in Riparian Areas That Can Provide Coarse Woody Debris to Streams. *Forest Science* 36:790-801.

This article uses geometric and empirical equations to determine the conditional probability of a tree adding coarse woody debris to a stream based on tree size and distance from a stream, called a basal area factor. Resource managers can use prisms or wedge devices before timber harvesting in riparian areas to identify specific trees that would potentially add woody debris to a stream.

Scott, J.B., C.R. Steward, and Q.J. Stober. 1986. Effects of Urban Development on Fish Population Dynamics in Kelsey Creek, Washington. *Transactions of the American Fisheries Society* 115:555-567.

A 30 month study of the comparative dynamics of fish populations inhabiting Kelsey Creek (an urban watershed) and a nearby pristine control stream suggests that urban development has resulted in a restructuring of the fish community. Marking and outmigrant studies indicated that environmental disruptions in urban streams do not result in the displacement of the salmonid inhabitants (in Kelsey Creek watershed). Total biomass of fish remains similar, but composition differs markedly. Ages 0 and 1 cutthroat become the majority of the fish community in Puget Sound urbanized streams, while coho salmon are displaced. Growth rates of cutthroat are faster in streams that have experience canopy loss (25% loss) and smolt outmigration primarily occurs as age 1 fish (1-2 years earlier that from undisturbed streams), due to faster growth. The percentage of cutthroat trout in Lake Washington streams in directly proportional to the percentage of impervious area in basin, while diversity of fish species is inversely related to impervious area percentage. Increases in bed scour and gravel movement in urban streams reduces sculpin biomass by 20 to 99%. Adult sculpins and eggs experience extensive mortality during floods in unstable substrates. The large size of coho eggs and the depth they are deposited in stream gravels increase the threat of hypoxia as a source of embryo mortality where fine sediments prevail. Channel modifications in urban streams (loss of channel complexity) reduce pool and side channel habitat for coho salmon, while cutthroat trout show greater behavior flexibility and are found in a variety of habitat types.

Sheldon, D., T. Hruby, P. Johnson, K. Harper, A. McMillan, T. Granger, S. Stanley, E. Stockdale. March 2005. Wetlands in Washington State – Volume 1: A Synthesis of the Science. Washington State Department of Ecology. Publication #05-06-006. Olympia, WA.

A synthesis of the most current science regarding freshwater wetlands in Washington and how they function; the effects of human activities on Washington's freshwater wetlands and their functions; and the tools used to protect and manage freshwater wetlands and their functions and values.

Snohomish County. 2001. Lake Stevens Urban Growth Area (USGA) Plan. Snohomish County Planning Commission, Snohomish County, Everett, Washington.

U.S. Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers Wetlands Delineation Manual. Technical Report Y-87-1. U.S. Waterways Experiment Station, Vicksburg, Mississippi.

The manual describes methods to be used for delineating the jurisdictional boundary of a wetland using the three parameters: water regime/hydrology, soils, and vegetation. It is required to be used by all federal jurisdictions.

U.S. Environmental Protection Agency. 1994. Partnerships and Opportunities in Wetland Restoration; Proceedings of a Workshop, Seattle, Washington, April 16 – 17, 1992. USEPA Region 10, Seattle, Washington.

Proceedings of a well-attended conference in 1992. Papers presented cover a broad range of wetland-related topics, and present numerous perspectives: agencies, researchers, conservation groups, applicants, and consultants.

URS Greiner Woodward Clyde (URS). 2000. Pierce County Endangered Species Act Response Plan: Evaluation of County Policies, Regulations, and Programs. Prepared for Pierce County, Washington by URS Greiner Woodward Clyde in association with Adolfson Associates, Inc., Seattle, Washington.

A summary of riparian buffer research, including 13 papers on Large Organic Debris (LWD) recruitment, estimated that a 131 foot buffer would achieve 80% of LWD function.

URS Corporation (URS). 2001. Whatcom County Endangered Species Act Evaluation Report. Prepared for Whatcom County, Washington by URS Corporation, Seattle, Washington.

A summary of riparian buffer research, including 13 papers on Large Organic Debris (LWD) recruitment, estimated that a 131 foot buffer would achieve 80% of LWD function.

Van Sickle, J. 2000. Modeling Variable-Width Riparian Buffers, With an Application to Woody Debris Recruitment. *In*: P.J. Wigington and R.L. Beschta (eds.), 2000. Riparian Ecology and Management in Multi-Land Use Watersheds. American Water Resources Association, Middleburg, VA, TPW-00-2, 616 pp.

Van Sickle uses the model discussed in Weller et al. (1998: Ecological Applications 8, 1156-1169) that demonstrates variable-width buffers transmit more runoff materials, on average, from adjacent landscapes into a stream than would a fixed-width buffer of the same mean width. Van Sickle expands upon the Weller et al. model to describe general buffer information that extends the model framework, analytical methods, and key result to riparian functions including large woody debris delivery, stream shading, and bank stabilization. Each are riparian functions dependent upon the width of the buffer.

Van Sickle, J. and S.V. Gregory. 1990. Modeling Inputs of Large Woody Debris to Streams from Falling Trees. *Can. J. For. Res.* 20:1593-1601.

Van Sickle and Gregory incorporated tree distances, heights, and species of Large Woody Debris (LWD) source tree to devise a model estimating the woody debris delivery to streams from falling trees. The model can be used to predict relationships between Riparian Management Zone (RMZ) width and relative LWD inputs rates. The model can also explore effects of other variables in the RMZ design, such as the proportion and size of trees harvested within the zone.

Washington State Department of Community, Trade and Economic Development. 2003. Critical Areas Assistance Handbook: Protecting Critical Areas within the Framework of the Growth Management Act. Olympia, Washington.

This guidebook is designed to help Washington communities design locally appropriate programs for designating and protecting critical areas.

Washington State Department of Community, Trade and Economic Development. 2003. Critical Areas Assistance Handbook: Protecting Critical Areas within the Framework of the Growth Management Act. Olympia, Washington.

This guidebook is designed to help Washington communities design locally appropriate programs for designating and protecting critical areas.

Washington State Department of Ecology. 1993. Washington State Wetland Rating System for Western Washington. Ecology Publication # 93-74, Olympia, Washington.

The Washington state wetland rating system is a method for grouping wetlands into one of four categories based on their sensitivity to disturbance, whether they can be easily replaced, the presence of highly valued characteristics (such as threatened and endangered species), and habitat structure. It is often used as the basis for setting buffer requirements when development occurs in, or near, wetlands. The rating system for Western Washington is intended to be used in wetlands on the west side of the Cascade crest.

Washington State Department of Ecology. 1993. Restoring Wetlands in Washington. Ecology Publication # 93-17, Olympia, Washington.

Planning booklet aimed at novices and neighborhood groups primarily, but contains many ideas, checklists, etc. that even experienced professionals would find helpful.

Washington State Department of Ecology. 1994. Guidelines for Developing Freshwater Wetlands Mitigation Plans and Proposals. Ecology Publication # 94-29, Olympia, Washington.

This report provides guidance for those planning to undertake restoration, creation, or enhancement of freshwater wetlands to compensate for unavoidable impacts. It describes an outline that should be followed when submitting plans and proposals.

Washington State Department of Ecology. 1997. Washington State Wetland Delineation Manual. Ecology Publication # 96-94, Olympia, Washington.

The manual describes methods to be used for delineating the jurisdictional boundary of a wetland using the three parameters: water regime/hydrology, soils, and vegetation. It is required to be used by all state and local jurisdictions (RCW 36.70A.175) and produces the same boundary as the U.S. Army Corps of Engineers 1987 manual.

Washington State Department of Ecology. 1999. Methods for Assessing Wetland Functions Volume 1: Riverine and Depressional Wetlands in the Lowlands of Western Washington – Parts 1 and 2. Ecology Publication # 99-115, Olympia, Washington.

The methods provide relatively rapid, scientifically valid procedures for assessing how well wetlands perform functions, such as improving water quality, reducing floods, and providing wildlife habitat. The methods described in this volume can be used in riverine and depressional wetlands in Western Washington that are in the lowlands and the foothills of the Olympic and Cascade mountains. The Department of Ecology recommends that these methods be used only by people who have completed the five-day training workshop offered by Ecology.

Washington State Department of Ecology. 2004. Washington State Wetland Rating System for Western Washington – Revised. Ecology Publication # 04-06-025, Olympia, Washington.

The revised Washington state wetland rating system is a method for grouping wetlands into one of four categories based on their sensitivity to disturbance, whether they can be easily replaced, the presence of highly valued characteristics, and habitat structure. It is often used as the basis for setting buffer requirements when development occurs in, or near, wetlands. The rating system for Western Washington is intended to be used in wetlands on the west side of the Cascade crest.

Washington State Department of Ecology, U.S. Army Corps of Engineers Seattle District, and U.S. Environmental Protection Agency Region 10. March 2006. Wetland Mitigation in Washington State - Part 1: Agency Policies and Guidance (Version 1). Washington State Department of Ecology Publication # 06-06-011a. Olympia, WA.

This document does not provide new requirements for wetland mitigation, but rather attempts to compile all of the existing information, including currently available science, and current agency policies on mitigation. It provides an overview of the role of the agencies play in regulating wetlands and some of the factors that go into agencies' wetland permitting decisions in regards to mitigation. This document also updates and replaces the portion of the 1997 Ecology publication, *How Ecology Regulates Wetlands*, pertaining to wetland mitigation.

Washington Department of Ecology, U.S. Army Corps of Engineers Seattle District, and U.S. Environmental Protection Agency Region 10. March 2006. Wetland Mitigation in Washington State - Part 2: Developing Wetland Mitigation Plans (Version 1). Ecology Publication # 06-06-011b. Olympia, WA.

Ecology, the Corps, and EPA have jointly developed this updated guidance on wetland mitigation with the goal of improving the success of compensatory mitigation in Washington State overall and in the context of a regional landscape approach. This new guidance is intended to update and replace the previously published 1994 *Guidelines for Developing Freshwater Mitigation Plans and Proposals.*

APPENDIX A

City of Lake Stevens
Critical Area Maps

APPENDIX B

City of Lake Stevens
BAS Field Visits – Streams and Wetlands

APPENDIX C

City of Lake Stevens
BAS Addendum