Interstate 90 Snoqualmie Pass East Mitigation Development Team

Recommendation Package

Prepared for

Washington State Department of Transportation

Federal Highway Administration

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Executive Summary

What is the purpose of this recommendation package?

The I-90 Snoqualmie Pass East Project is being proposed and developed by the Washington State Department of Transportation (WSDOT) and the Federal Highway Administration. WSDOT convened an Interdisciplinary Team (IDT) to help develop the purpose and need for this transportation project. At that time, WSDOT recognized the importance of planning connectivity during the early stages of the project, and asked the IDT to integrate ecological connectivity into the wide array of other project objectives. The IDT convened a multi-agency team of biologists and hydrologists, known as the Mitigation Development Team or MDT, to provide technical support regarding ecological connectivity and the development of an environmental mitigation strategy.

This recommendation package contains mitigation strategies, performance standards, and recommendations to guide development of ecological and hydrologic connectivity improvements for the I-90 Snoqualmie Pass East Project.

This recommendation package is focused on evaluating the degree to which proposed highway designs meet the MDT’s ecological connectivity objectives. Subsequent efforts will combine this recommendation package with a conceptual mitigation strategy to produce a comprehensive environmental mitigation package.

What is the purpose of this project?

The project corridor is located in Kittitas County, Washington, along a 15-mile stretch of I-90 that passes through the Wenatchee National Forest. The corridor begins on the eastern side of Snoqualmie Pass at Milepost (MP) 55.1 in Hyak and ends at MP 70.3 near Easton. The main objectives of the project are to reduce

Clockwise from top, marten, Canada lynx, and wolverine are some of the species expected to benefit from wildlife crossing structures in the project area.
impacts on safety and highway operation from avalanches and rock fall, replace failing concrete pavement, add lanes to reduce congestion, and improve ecological connectivity across I-90.

What is ecological connectivity? (Chapter 1)

The MDT developed a definition for ecological connectivity that has guided our evaluation of the best ways to incorporate ecological connectivity into the I-90 project design options.

**The MDT defined ecological connectivity as:**

*The movement of organisms and the occurrence of ecological processes across an ecosystem over time.* Intact ecosystems are structured by dynamic processes that create a shifting mosaic of various habitat patches. The ability of organisms to disperse freely through this mosaic is important to allow genetic exchange, re-colonization of habitats, and maintenance of functioning food webs. Genetic variability is a species’ insurance against localized or population level disturbances and ultimately improves an organism’s evolutionary potential. The ultimate outcome is natural sustaining populations across an ecosystem over time.

Because hydrologic processes are central to maintaining ecological connectivity in the project area, we emphasized maintaining the continuity of these processes. We defined hydrologic connectivity as “maintaining natural flow paths that transmit water, sediment, and nutrients to and through watersheds, aquifers, and streams.” Throughout this recommendation package, we use the term ecological connectivity as the general term that incorporates both wildlife and hydrologic connectivity.

Why is ecological connectivity important in the project area? (Chapters 1 and 2)

The project area has high biodiversity. The mountainous topography surrounding the project area creates a substantial rain-shadow effect. The resulting gradient in precipitation supports a variety of different plant associations and produces a diverse assemblage of habitats within a relatively short distance.

At a regional scale, Snoqualmie Pass is recognized as a critical link for the north-south movement of wildlife living in the Cascade Range. This is a critical connection because extensive areas where natural habitats and wildlife are protected (national forests, wilderness areas, and national parks) occur both to the north and south of the project area. The I-90 corridor represents the narrowest width, west to east, of public land in Washington’s Cascade Mountains (Exhibit ES-1). Numerous studies have identified the I-90 corridor as a critical area for connecting species populations in the Pacific Northwest. National Forest lands in this area are part of the Snoqualmie Pass Adaptive Management Area and are managed with special emphasis on supporting ecological connectivity.
Land Ownership, Wilderness, and National Parks in the Vicinity of the Project
Exhibit ES-1
Adequate connections between habitats and hydrologic features on either side of I-90 are necessary for the continued health of the project area's diverse ecosystems. Over the past several years, land conservation efforts have added approximately 112 square miles to the National Forest system in the project area. The goals of these efforts are to protect old-growth forest, provide larger contiguous blocks of forest habitat, and facilitate habitat and hydrologic connections across I-90.

At the project scale, the U.S. Forest Service has identified more than 49 species of amphibians, mammals, and birds that are closely associated with late-successional habitat (mature or old growth forest) in the project area. Information about wildlife roadkill on I-90, landscape permeability, and wildlife use of culverts and habitat adjacent to I-90 indicate that the project area provides important linkages for the local movement of wildlife, as well as broader ecological connectivity between the north and south Cascades. Studies identified three significant north-south linkage zones within the I-90 corridor, each with its own distinct species assemblages.

The project area is located in the headwaters of the Yakima River and is rich in wetlands and streams. Hydrologic connectivity in the headwaters provides water for fish, recharges groundwater, and improves water quality in the upper Yakima River and its tributaries.

What impact does I-90 have on ecological connectivity? (Chapters 1 and 2)

The existing highway is a partial or complete barrier to wildlife movement. On the average day, 27,000 vehicles pass through the project area. On busy weekends, the number increases to as many as 52,000 vehicles. If averaged over the course of the day, this is one vehicle every 3.2 and 1.6 seconds, respectively.

Over the next 20 years, traffic volumes are expected to double. To accommodate this increased traffic, the proposed I-90 project will widen the highway from 4 to
6 lanes. The combined effects of increased traffic volume, a wider highway, and increased traffic speed could result in a nearly complete barrier to most species. Structures that provide ecological connectivity would support linkages for multiple species’ ecological processes over time.

I-90 also impacts important hydrologic processes and is currently a physical barrier to important aquatic habitats. Existing stream crossing structures create barriers to aquatic species migration and degrade habitat within channels, floodplains, and associated wetlands. Highway fill and drainage systems alter the hydrology of wetlands above and below the highway and contribute to water quality problems in the Yakima River Valley.

**What are the benefits of providing ecological connectivity? (Chapters 1 and 2)**

Improving ecological connectivity as part of the project can provide the following benefits:

- Improves safety for humans and animals by keeping animals off the roadway and reducing the number of vehicle-wildlife collisions.
- Removes barriers to species movement, making it possible to reconnect plant and animal populations and improve genetic flow between these populations.
- Provides the opportunity to reconnect and restore hydrologic flows, channel migration, nutrient cycling, and water quality.
- Supports conservation and management efforts for game species, salmon, and species listed under the Endangered Species Act.

Between 1991 and 2001, over 240 deer and elk were killed in wildlife-vehicle collisions on I-90 in the project area. These collisions represent a serious safety issue for motorists as well as an impact on wildlife populations. Exhibit ES-2 shows the frequency of wildlife-vehicle collisions in the project area. By reducing roadkill as a source of mortality and increasing the potential for movement of individuals among populations, ecological connectivity can enhance game populations, contribute to the recovery of listed species, and potentially reduce the need to list additional species. Studies on the effectiveness of fencing in combination with wildlife crossings show that wildlife-vehicle collisions can be reduced by 80 percent when these measures are used.

In addition, this project has the potential of improving water quality and restoring hydrological elements that feed the upper Yakima River. Over $120 million have been invested Chinook salmon would benefit from improved water quality and access to tributary habitat.
Known Deer and Elk Roadkill Locations in Project Area (1991 to 2001)
Exhibit ES-2
in salmon restoration in the Upper Yakima River Basin, and the hydrological elements incorporated into the design of this project will help protect these investments.

How did the MDT determine the ecological connectivity needs in the project area? (Chapters 2 and 3)

The MDT’s first task was to review the existing scientific information and site-specific technical report data to determine the existing ecological conditions within the project area. Among other topics, we considered high-mobility species, low-mobility species, roadkill data, fish passage, landscape permeability, existing habitat conditions, aquatic habitat connectivity, and hydrologic function. At the project-wide scale, we identified three generalized north-south linkage zones—the Gold Creek Valley, Keechelus Lake to Amabalis Mountain, and the Easton Hill area. Within these zones, we also identified 15 Connectivity Emphasis Areas (CEAs) across the project area. Each CEA provides an opportunity to improve connectivity for a unique assemblage of species. CEAs range in complexity from single stream crossings to multiple stream crossings with associated wetlands and areas of diffuse surface flow, to upland areas that are important movement routes for wildlife.

We also used background information to develop a short list of desired ecological conditions and associated broad objectives to meet ecological connectivity needs at the project-wide scale. To add greater specificity to our objectives and to develop criteria for evaluating different highway design options, we expanded each broad objective into a longer list of specific performance standards. We then used these performance standards along with background information about conditions at each CEA to develop CEA-specific connectivity objectives that accounted for differences in species assemblages and the presence of special habitat types (e.g., wetlands, residual old-growth forest, talus slopes). CEA-
specific objectives addressed wildlife activity, habitat linkages, hydrology, and terrain features. Within each CEA we also identified Hydrologic Connectivity Zones (HCZs) where restoring wetland and seepage flow through the roadway is important.

The I-90 project design team collaborated with the MDT to develop alternative conceptual designs for the highway at each CEA. The design team also developed some designs independently. The IDT requested that the MDT evaluate the likely performance of the resulting array of different design options to determine which design options would meet ecological connectivity objectives.

**How did the MDT evaluate whether proposed design options would meet ecological and hydrologic connectivity needs at the CEA and project-wide scales? (Chapters 3 and 4)**

At the CEA scale, we based our evaluation on a subset of our performance standards that were relevant to the effectiveness of the proposed designs. We translated these performance standards into questions, which we asked for each design option in light of CEA-specific connectivity objectives. How well a design option met performance standards and CEA-specific objectives determined the sufficiency of that option.

To evaluate project-wide connectivity, we used a similar approach. Early in the process of working on this project, we developed broad objectives that would help us evaluate whether project designs would meet ecological connectivity needs. These objectives are project-wide analogs of CEA-scale performance standards. We translated these project-wide objectives into a set of questions, which we used to assess project-wide connectivity.

**What kinds of wildlife crossings do the MDT recommend to improve ecological connectivity on I-90? (Chapter 2)**

To be most effective, structures should be located in areas of high landscape permeability—meaning areas where terrain and habitat converge. Crossing structures are more effective for some species if they contain habitat, rather than simply being physical connections between habitat on opposite sides of the highway. For instance, lower mobility animals will feel more secure crossing a structure if it contains hiding cover. Different animals show different preferences for crossing structures.

**Small structures**, such as round culverts and small box culverts that are typically installed for drainage under highways, are also used as crossings by a variety of small mammals, amphibians, and reptiles.

Examples of animals that would use small structures include:
- Pika
- Western jumping mouse
- Pacific water shrew
- Bushy-tailed woodrat
- Mountain beaver
- Cascade frog
- Larch Mountain salamander
- Alligator lizard
- Western skink
- Rubber boa

Example of a small structure
**Medium structures** include box culverts or small bridges that are at least 5 feet wide or tall but have less than approximately 12 feet of vertical clearance above the ground and 100 feet of width (inside the structure). Medium structures are used by many of the same animals that use small structures. Deer also use these, although they tend to use larger structures more readily.

**Large structures** include bridge spans that provide a wildlife passage that is at least 16 feet high (to provide 12 feet of clearance over the typical 4-foot snow depth) and 100 feet wide, and crossings that pass over the highway. Large structures provide the greatest degree of openness, and allow for passage by the largest animals and the broadest range of animals.

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**Examples of animals that would use medium structures include:**
- Mule deer
- Rocky Mountain elk
- Black bear
- Grizzly bear
- Mountain goat
- Mountain lion
- Gray wolf
- California wolverine
- Canada lynx

**Examples of animals that would use large structures include:**
- Mule deer
- Rocky Mountain elk
- Black bear
- Grizzly bear
- Mountain goat
- Mountain lion
- Gray wolf
- California wolverine
- Canada lynx

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**Do wildlife crossing structures work? (Chapter 2)**

Wildlife crossing structures have been shown to work remarkably well when carefully placed on the landscape and combined with fencing, retaining walls, or natural barriers such as cliffs. In monitoring 22 crossing structures over a 5-year period on the Trans-Canada Highway, Clevenger (2002) reported 37,379 individual wildlife passes by just ungulates and carnivores. Recent reports indicate that there have now been over 70,000 crossings of ungulates and carnivores. Furthermore, these same crossing structures were also commonly used by smaller animals, such as hare, weasels, marten, and mice. Exhibit ES-3 shows the type and numbers of animals that use overpasses and underpasses in Banff National Park in Canada.
What factors help make crossing structures successful? (Chapter 2)

The MDT identified other site-specific measures needed to encourage wildlife to use the crossing structures and to reduce vehicle-wildlife collisions:

- Keep the length of the crossings as short as possible to encourage wildlife use.

- Where feasible, and considering other project needs, keep eastbound and westbound lanes close together, with little median.

- Provide a minimum 12-foot vertical clearance over snowpack for large, high-mobility wildlife species.

- Provide fencing or other methods to guide animals to the structures.

The proximity of adjacent habitats is important, and for many species, habitat elements within the crossing structure itself (such as root wads, logs, and vegetation) will encourage use, particularly for low-mobility species. The capacity of larger structures to accommodate these elements is an added benefit.

Evidence from studies of existing crossings indicates that vertical clearance of at least 12 feet is needed for unrestricted use by the species in the project area. To maintain year-round passability, this clearance needs to be above the snowpack level, which averages 6 feet at Gold Creek, diminishing to an average of 4 feet at the Kachess River crossing. Clearance of up to 20 to 30 feet under certain structures is desirable to allow native vegetation to become established.
Wildlife crossing structures are dramatically more effective if they are accompanied by fencing or other exclusion methods to guide animals to the structures. Fencing locations should take into account roadkill information, placement of wildlife crossing structures, and terrain. Wildlife-vehicle collisions on the Trans-Canada Highway were reduced by 80 percent for all animals and 90 percent for ungulates using a combination of wildlife crossings and fencing. These reductions occurred despite a significant increase in traffic volume over the same time period (Clevenger 2002). In some places, retaining walls can provide wildlife exclusion in place of fencing; vertical walls also reduce the amount of fill quantities and lessen wetland impacts.

Wildlife crossing structures should be designed and managed to minimize human disturbance. Therefore, shielding wildlife from traffic noise and lights in the vicinity of crossing structures is essential.

What are the MDT’s findings? (Chapters 3, 4, and 5)

At every CEA except Cedar Creek and Telephone Creek, we found that at least one design option would meet ecological connectivity objectives. Because of steep terrain, we could not find constructible options at Cedar Creek and Telephone Creek that would meet our wildlife connectivity objectives. At the Gold Creek, Price-Noble Creek, and Easton Hill CEAs, multiple design options met connectivity objectives. At these CEAs, we ranked the options in terms of best providing for ecological connectivity needs. Recognizing that CEA-scale connectivity was necessary, but not sufficient to provide project-wide connectivity, we went on to evaluate how connectivity would be improved at this larger scale.

We found that project-wide wildlife connectivity objectives were likely to be met by (1) combining design options at CEAs that meet CEA-specific objectives, (2) installing small or medium crossing structures at upland sites, and (3) implementing recommended performance standards outside of CEAs. We expect that this combination of features would profoundly improve ecological connectivity relative to the existing condition.

The issues that challenged us most about project-scale connectivity were lack of connections for the subalpine fir-mountain hemlock habitats and the lack of connectivity for large, high-mobility species in the 3.5-mile stretch of highway between Toll Creek and Hudson Creek (the Amabalis Mountain CEAs). We found that both of these issues did not change our professional judgment that project-wide connectivity objectives would be met.

The MDT’s spacing objective was to have one large structure approximately every mile. Constructability constraints prevented meeting this objective in the Keechelus Lake (depending on alignment) and Amabalis Mountain CEAs.

The MDT also recommends a combination of structure types (i.e., overcrossing and undercrossing) that would be most beneficial for the variety of species to be
served. We recommend additional small or medium crossings at an interval of approximately every 820 feet throughout the corridor to further support the linkage of upland habitats and the movement of smaller animals.

From a hydrologic perspective, project-wide connectivity needs are predominantly met by design options that meet objectives within CEAs. Our project-wide evaluation revealed no significant gaps in hydrologic connectivity that needed to be addressed.

The MDT’s findings at both the CEA and project-wide scales are summarized together in Exhibit ES-4 and in Chapter 5. Brief summaries of each CEA, except Coal Creek, follow Exhibit ES-4.
### Summary of CEA Options

#### Option A
- 120' bridge
- 1 HCZ
- 2-800' bridges
- 2 HCZs
- 2-120' bridges
- 3-120' bridges
- 4 HCZs
- 3 HCZs
- 120' bridge
- 6'x5' culvert
- >4' culvert
- 6' culvert
- 140' bridge
- 40' bridge
- 10' culvert
- 4' culvert
- 6' culvert
- 2-6' culverts
- 2-8' culverts
- 4' culvert
- 3' culvert
- 5' x 4' culvert
- 2' culvert

#### Option B
- 1,200' EB/1,000' WB bridge
- 100' wildlife bench
- 120' bridge
- 2-800' bridges
- 2 HCZs
- 3 HCZs
- 240' bridge
- 1 HCZ
- 120' bridge
- 240' bridges
- 2 HCZs
- 5 HCZs
- 3-120' bridges
- 2 HCZs
- 18' x 10' culvert
- 120' bridge
- 8 HCZs
- 8' x 5' culvert
- 24' culvert
- 3 HCZs
- 120' bridge (EB and WB)
- 120' bridge
- Wildlife Overcrossing EB and WB
- 120' bridge
- Wildlife Overcrossing EB and WB
- 120' bridge
- Wildlife Overcrossing EB and WB
- 120' bridge

#### Option C
- 120' bridge
- 300' bridge
- 2-6' culverts
- 6' culvert
- 6' culvert
- 6' culvert
- 4' culvert
- 6' culvert
- 6' culvert
- 6' culvert
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Summary of Gold Creek (Valley) CEA

The Gold Creek CEA is located between MP 55.2 and MP 55.8, near Snoqualmie Pass. Gold Creek crosses I-90 under 138- and 126-foot bridges and empties into Keechelus Lake at the northwest tip of the lake. This CEA connects old growth stands in mountain hemlock-subalpine fir forests and provides important hydrologic functions for Gold Creek. Gold Creek represents a critical area for linking the Alpine Lakes Wilderness to the Norse Peak Wilderness, which, in turn, links to other wilderness areas and national parks throughout the Washington Cascade Mountains.

What are the connectivity objectives at Gold Creek?

- Provide a high level of year-round connectivity for the high- and low-mobility species associated with the mountain hemlock-subalpine fir forests, riparian habitats, wetlands, and floodplains. Year-round connectivity will require high structures (minimum 18 feet) due to winter snowpack.
- Provide a high level of connectivity across the reservoir bed for approximately 9 to 10 months of the year.
- Significantly reduce wildlife-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.
- Restore natural channel migration processes and reduce floodplain confinement, particularly upstream of I-90 where floodplains and associated wetlands are not inundated by Keechelus Lake; restore capacity to convey flood flows, sediment, and debris through the Gold Creek crossing structure.
- Provide fish passage and habitat improvements for threatened bull trout for the full range of lake elevations.
- Improve water quality by properly treating stormwater and highway runoff, and minimizing de-icer chemical use.

Do the Gold Creek design options meet the connectivity objectives?1

<table>
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<tr>
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</tr>
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<tbody>
<tr>
<td>A</td>
<td>120' bridge - wildlife 1,100' EB bridge 900' WB bridge - channel migration/wildlife</td>
<td>🌟🌟🌟 Yes</td>
<td>Option A places the wildlife crossing bridge to the west close to mountain hemlock-subalpine fir habitat at the edge of the floodplain where many terrestrial species would encounter it. The long span over Gold Creek would provide channel migration over most of the historic floodplain and would connect/restore wetlands.</td>
</tr>
<tr>
<td>B</td>
<td>1,200 EB bridge/ 1,000 WB bridge/ 100' wildlife corridor under west edge, and channel migration area to the east</td>
<td>🌟🌟 Yes</td>
<td>Option B wildlife connectivity is farther from mountain hemlock-subalpine fir habitat and would require wildlife traveling along the edge of the floodplain to move out toward the stream channel to find the crossing; this may be an impediment to use, especially by low-mobility species. Hydrologic performance would be the same as Option A.</td>
</tr>
<tr>
<td>C</td>
<td>120' bridge - wildlife 300' bridge - channel migration/wildlife</td>
<td>🌟🌟🌟 No</td>
<td>Option C would provide less connectivity for wildlife because of less year-round open space due to the reservoir and the height of the 120' bridge. The 300' bridge does not span the channel migration zone and wetlands would be significantly less restored/connected.</td>
</tr>
<tr>
<td>D</td>
<td>120' bridge - wildlife 700' bridge - channel migration/wildlife</td>
<td>🌟🌟🌟 Yes</td>
<td>Option D’s 120’ bridge would provide some wildlife connectivity as Option A, however. 700’ bridge would provide less passage for wildlife across reservoir bed. Minimum acceptable level of hydrologic connectivity, with wetland restoration/connection reduced compared to Option A or B.</td>
</tr>
</tbody>
</table>

1 Stars indicate the MDT’s recommendation ranking; three stars = highest.
Summary of Keechelus Lake CEAs

Keechelus Lake is an obstacle to movement by terrestrial species. Opinions differ, however, about how large an obstacle. The MDT found that, relative to other portions of the proposed project, CEAs along the lake do not generally coincide with primary areas of wildlife movement or special habitats. High pool elevations that inundate some structures near the shoreline typically last for no more than 2 to 3 months, so proposed structures would provide some crossing opportunities during most times of the year. Consequently, the MDT did not believe that large crossing structures would be needed along the lake to meet CEA-specific or project-wide connectivity objectives. The MDT believes the single design option for each CEA described below would meet the connectivity objective for that CEA.

Rocky Run Creek CEA

The Rocky Run Creek CEA is located between MP 56.7 and MP 56.9, with the creek originating above 4,800 feet elevation at Lake Lillian. The forest habitat adjacent to this CEA is the Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations. The creek flows into the east side of Keechelus Lake and has a fairly steep gradient, although several fish species use this system. The existing I-90 crossing over Rocky Run Creek is a 40-foot-long bridge eastbound and two 6-foot pipe culverts westbound. The MDT believes the proposed single design option of twin 120-foot bridges would meet the connectivity needs of wildlife and aquatic organisms, while passing flood flows and debris.

What are the connectivity objectives at Rocky Run Creek?

- Provide moderate level of connectivity for high- and low-mobility species associated with the mountain hemlock/subalpine fir species assemblage zone. Keechelus Lake and poor geographic fit limit the connectivity options at this site.
- Restore capacity for flood and debris flow at the Rocky Run Creek crossing structure.
- Provide fish passage for the full range of lake elevations.

Wolfe Creek CEA

The Wolfe Creek CEA is located between MP 57.1 and MP 57.3, with the creek originating above 4,800 feet elevation. The forest habitat adjacent to this CEA is the Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations. The creek has a very steep gradient and provides limited fish habitat, although Pacific giant salamanders and tailed frogs are relatively common. Currently, the creek passes under I-90 in a 6-foot box culvert and empties into the east side of Keechelus Lake. The MDT believes the single design option, a 25-foot by 8-foot bottomless culvert westbound and a 20-foot by 10-foot bottomless culvert eastbound, would meet the connectivity needs of wildlife and aquatic organisms, while passing flood flows and debris.

What are the connectivity objectives at Wolfe Creek?

- Restore capacity for flood and debris flow at the Wolfe Creek crossing structures.
- Provide fish passage for the full range of lake elevations. Provide aquatic organism connectivity.
Resort Creek CEA
The Resort Creek CEA is located between MP 59.3 and MP 59.7, with the creek originating at 4,600 feet elevation. The forest habitat adjacent to this CEA is the Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations. Currently, Resort Creek flows under I-90 in a 6-foot pipe culvert that is a barrier to fish passage, and drains into Keechelus Lake. The MDT has identified a design option for each of the four road alignment alternatives at Resort Creek that would meet wildlife and hydrologic connectivity needs at this CEA.

What are the connectivity objectives at Resort Creek?
- Significantly reduce wildlife-vehicle accidents in this high roadkill zone. This will require wildlife fencing around the crossing structures.
- Provide a moderate level of connectivity for smaller species across the reservoir bed of Keechelus Lake during drawdown.
- Restore capacity for flood and debris flow at the Resort Creek I-90 crossing structure.
- Provide fish passage for the full range of Keechelus Lake elevations.
- Restore habitat and aquatic connectivity along the old highway alignment.
- Restore channel migration on the Resort Creek alluvial fan and maintain wetland flow paths on the Resort Creek floodplain.
- Improve water quality by properly treating stormwater and highway runoff and minimizing the use of de-icer chemicals.

Townsend Creek CEA
The Townsend Creek CEA is located between MP 60.5 and MP 60.7. The creek originates at about 4,000 feet elevation and passes under I-90 in a 6-foot box culvert before it empties into Keechelus Lake. The MDT believes the single design option, a 25-foot by 12-foot bottomless culvert, would meet the terrestrial and aquatic connectivity needs at this CEA.

What are the connectivity objectives at Townsend Creek?
- Significantly reduce wildlife-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.
- Provide a moderate level of connectivity for smaller species across the reservoir bed during drawdown.
- Restore habitat and aquatic connectivity along the old highway alignment.
- Restore capacity for flood and debris flow at the Townsend Creek I-90 crossing structure.
- Provide fish passage for the full range of lake elevations.
Summary of Price and Noble Creeks CEA

The Price and Noble Creeks CEA is located between MP 60.7 and MP 61.9. Price Creek crosses under I-90 in a 10-foot box culvert and drains into the Yakima River downstream of Keechelus Dam. Noble Creek crosses under I-90 in a 4-foot pipe culvert, and also flows into the Yakima River. The area from Keechelus Dam to the Price Creek rest area (MP 60.9 to MP 61.2) occurs within one of the three highest deer/elk roadkill concentration areas in the project boundaries.

What are the connectivity objectives at Price and Noble Creeks?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snow loads.
- Connect special soil type (K254) and the associated low-mobility species.
- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This would require wildlife fencing around the crossing structures.
- Construct wetlands and restore wetland flow paths on both sides of the highway. Removing fill and constructing wetlands at the Sno-park would provide good opportunities for mitigation of project wetland impacts.
- Restore natural flow paths and delivery of water from the alluvial fan east of Noble Creek to downslope wetlands and aquifers on the Yakima River floodplain. Restore capacity for flood and debris flow at the Price Creek and Noble Creek crossing structures. Restore channel migration and floodplain processes at Price and Noble creeks.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.

Do the Price-Noble design options meet the connectivity objectives?1

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<tbody>
<tr>
<td>A</td>
<td>120’ bridge at unnamed creek 800’ bridge Price/Noble 800’ bridge east wetland 1 HCZ</td>
<td>⭐⭐ Yes</td>
<td>Option A provides nearly double the openness of Option B, providing conditions favorable to use by both high- and low-mobility species. Long bridges over hydrologic features provide highest level of restored hydrologic connectivity.</td>
</tr>
<tr>
<td>B</td>
<td>120’ bridge at unnamed creek 600’ bridge Price/Noble 2 HCZs</td>
<td>⭐ Yes</td>
<td>Option B provides limited vertical clearance for multi-span bridge at the creeks, eliminating likely performance for high- and low-mobility species.</td>
</tr>
<tr>
<td>C</td>
<td>120’ bridge at unnamed creek 2 120’ bridges Price/Noble 2 HCZs</td>
<td>No</td>
<td>Option C does not meet connectivity objectives because disturbance from human activities associated with Sno-park would render nearby crossing structures ineffective; structures do not support the vegetation or habitat features for low-mobility species; structures do not meet hydrologic connectivity objectives for restoring wetland flow paths through Sno-park.</td>
</tr>
<tr>
<td>D</td>
<td>Wildlife overcrossing 120’ bridge at unnamed creek 2 120’ bridges Price/Noble 2 HCZs</td>
<td>⭐⭐⭐ Yes</td>
<td>Option D provides greatest potential for accommodating crossing preferences of all species known or expected in the CEA by combining paired undercrossings with an overcrossing (unlimited openness). Sno-park removal reduces potential for disturbance due to human activity. Hydrologic performance is least preferred of the three options.</td>
</tr>
</tbody>
</table>

1 Stars indicate the MDT’s recommendation ranking; three stars = highest.
Summary of Bonnie Creek CEA

The Bonnie Creek CEA is located between MP 61.9 to MP 62.5, and lies in the Upper Yakima River subwatershed. Bonnie Creek drains about 800 acres and flows under I-90 in a 6-foot circular metal culvert westbound and a concrete culvert eastbound. The MDT noted the presence of high-quality, late-successional habitat in this area, which is an important component of species diversity.

What are the connectivity objectives at Bonnie Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (a minimum of 16 feet) because of winter snow loads. Bridges over 20 feet high would provide light under the structures that would support plant life and increase the openness of the structure.
- Provide connectivity for late-successional habitat and species present in this area.
- Consider providing arboreal crossing structures for flying squirrels and other arboreal species.
- Significantly reduce wildlife-vehicle accidents in this high roadkill zone for deer and elk. This would require wildlife fencing around the crossing structures.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Restore natural streambed elevations, natural channel, floodplain, and wetland flow paths at both forks of Bonnie Creek.
- Minimize the need for destructive channel maintenance by providing crossing structures with proper grade and capacity.

Do the Bonnie Creek design options meet the connectivity objectives?1

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<tr>
<td>A</td>
<td>600' bridge 1 HCZ</td>
<td>🌟🌟🌟 Yes</td>
<td>Option A provides excellent linkage of the focal old growth and wetland habitat. Good light under structure. Restores natural channel functions and removes floodplain fill.</td>
</tr>
<tr>
<td>B</td>
<td>240' bridge 2 HCZs</td>
<td>🌟 No</td>
<td>Option B does not link old growth as well as Option A, but does connect wetlands. Reduced light under structure. Does not restore natural channel functions. Does remove floodplain fill.</td>
</tr>
<tr>
<td>C</td>
<td>16' x 10' culvert 2 HCZs</td>
<td>🌟 No</td>
<td>Option C does not link focal old growth or wetland habitat well. Poor light under structure. Does not restore channel functions or remove floodplain fill.</td>
</tr>
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1 Stars indicate the MDT’s recommendation ranking; three stars = highest.
Summary of Swamp Creek CEA

The Swamp Creek CEA is located between MP 62.5 and MP 63.4 in the upper Yakima River subwatershed. Swamp Creek drains 2,570 acres and flows under I-90 in an 8-foot double box culvert that drains into the Yakima River. The Swamp Creek CEA includes several HCZs that link wetlands east of Swamp Creek and near the Stampede Pass interchange to wetlands and shallow aquifers on the Yakima River floodplain. The terrestrial habitat was characterized as properly functioning, with the highest species biodiversity in the corridor. Animals appear to be channeled into this area by the topography of the Swamp Lake Valley.

What are the connectivity objectives at Swamp Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snowpack.
- Significantly reduce animal-vehicle accidents in this high roadkill zone.
- Connect special soil type (K254) and the associated low-mobility species.
- Provide passage for fish and other aquatic organisms moving between the Yakima River and Swamp Lake. Connectivity is important here because of several important breeding areas for amphibians on both sides of I-90, at Swamp Lake, and at ponds along the Yakima River. Existing culverts are passage barriers to juvenile fish.
- Improve water quality in the Swamp Creek CEA because I-90 passes closest to the Yakima River/Swamp Creek wetlands at this location.
- Restore natural channel, floodplain, and wetland flow paths at the Swamp Creek crossing structure. Restore natural surface and subsurface flow paths connecting extensive wetlands west of Swamp Creek to wetlands and aquifers on the Yakima River floodplain.
- Restore natural surface and subsurface flow paths connecting pockets of wetlands upslope of the Stampede Pass interchange to wetlands and aquifers on the Yakima River floodplain.

Do the Swamp Creek design options meet the connectivity objectives?¹

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<tr>
<td>A</td>
<td>240’ bridge 120’ bridge 4 HCZs</td>
<td>⭐⭐</td>
<td>Option A would meet wildlife connectivity objectives. However, we recommend raising the minimum height to 16 feet on the eastern bridge. Option meets hydrologic connectivity objectives. Bridges over Swamp Creek would provide excellent floodplain width to restore channel processes, fish passage, and sediment transport. HCZs near Swamp Creek and at the Stampede Pass interchange would restore flow paths between upslope wetlands and alluvial aquifers and wetlands on the Yakima River floodplain.</td>
</tr>
<tr>
<td>B</td>
<td>120’ bridge 120’ bridge 120’ bridge 5 HCZs</td>
<td>⭐⭐⭐</td>
<td>Option B would meet wildlife connectivity objectives. All bridges would meet minimum clearance height of 16 feet. Option provides 120’ less wetland and stream connection than Option A.</td>
</tr>
<tr>
<td>C</td>
<td>120’ bridge culvert 6 HCZs</td>
<td>No</td>
<td>Option C does not meet wildlife connectivity objectives because minimum clearance height is too low for year-round use by high-mobility species. Option does not connect wetland habitat as well as Options A and B.</td>
</tr>
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¹ Stars indicate the MDT’s recommendation ranking; three stars = highest.
Summary of Toll Creek CEA

The Toll Creek CEA is located between MP 63.5 and MP 64.2. Toll Creek flows under I-90 in a 4-foot-wide oval inlet and discharges from a 2-foot-diameter concrete outlet. The unnamed creek to the west of Toll Creek flows under I-90 in a 3-foot culvert and discharges from an 8-foot by 10-foot box culvert. The unnamed creek at the west end of this CEA is the focus of ecological connectivity efforts, not the Toll Creek crossing.

What are the connectivity objectives at Toll Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snowpack. High structures would provide light under the structures to support plant life and increase the openness of the structure.
- Connect special soil type (K254) and the associated low-mobility species.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Restore historical channel alignment of Toll Creek upstream of I-90.
- Restore natural movement of sediment, debris, and water through the Toll Creek crossing structure.
- Remove fill and restore wetland flow through the I-90 roadbed at the unnamed creek west of the Cabin Creek interchange.

Do the Toll Creek design options meet the connectivity objectives?1

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<tr>
<td>A</td>
<td>120’ bridge 6’ x 5’ culvert</td>
<td>🌟🌟🌟 Yes</td>
<td>Option A meets wildlife connectivity objectives and hydrologic connectivity objectives.</td>
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<td>B</td>
<td>Same as Option A</td>
<td>Yes</td>
<td>Option B is the same as Option A.</td>
</tr>
<tr>
<td>C</td>
<td>6’ x 5’ culvert</td>
<td>No</td>
<td>Option C does not meet wildlife connectivity objectives because it does not meet minimum height requirements. Option also does not meet hydrologic connectivity objectives because it does not restore wetland and floodplain flowpaths at the unnamed creek.</td>
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1 Stars indicate the MDT’s recommendation ranking; three stars = highest.
Summary of Amabalis Mountain CEAs

The 3.5-mile stretch of highway from Toll Creek to Hudson Creek is problematic in terms of connectivity and prompted debate among the MDT about project-wide sufficiency. This area includes the steep southern slope of Amabalis Mountain. The existing highway is cut into the mountainside, resulting in steep cut slopes on the north side and steep fill embankments on the south side. Proposed widening of the highway may lead to even higher cut slopes and fills. The steep slope of the terrain in the area leads to severe constructability constraints that limit the amount of clearance available for crossing structures under westbound lanes. Overcrossings are not possible because the ground surface south of the highway slopes away too rapidly. Consequently, constructability constraints would result in a 3.5-mile stretch of the project that does not have any crossing structures suitable for large, high-mobility terrestrial species. This is the only area where wolverine have been documented nearby.

Cedar Creek CEA

The Cedar Creek CEA is located between MP 64.5 and MP 64.7, and is a steep, confined stream flowing off Amabilis Mountain. It crosses under I-90 in a 4-foot box culvert. The MDT believes the single design, a 4-foot by 4-foot culvert with an associated HCZ, would meet the aquatic connectivity needs, but there were no constructible options that would meet the terrestrial connectivity objectives for this CEA.

What are the connectivity objectives at Cedar Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snowpack. High structures would provide light under the structures to support plant life and increase the openness of the structure.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Restore capacity for flow and debris passage at the Cedar Creek crossing.
- Provide a stream crossing structure that allows restoration of unconfined flow, channel processes, and shallow groundwater recharge on the terrace downslope of I-90.

Telephone Creek CEA

The Telephone Creek CEA, located between MP 65.5 and MP 65.7, has a drainage basin of 701 acres. The headwaters of Telephone Creek occur within a mature forest, and the creek drains into the Yakima River. The MDT believes the single design, a 4-foot by 4-foot culvert, would meet the aquatic connectivity needs, but there were no constructible options that would meet the terrestrial connectivity objectives for this CEA.

What are the connectivity objectives at Telephone Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snowpack. High structures would provide light under the structures to support plant life and increase the openness of the structure.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Restore capacity for flow and debris passage at the Telephone Creek crossing; allow unconfined channel development downstream of I-90.
- Connect natural talus habitat on both sides of the highway.
Summary of Hudson Creek CEA

The Hudson Creek CEA, located between MP 66.8 and MP 67.3, has a drainage area of 903 acres. The existing 2-foot-diameter culvert under I-90 is a complete barrier to fish passage at all flows. There are several seepage zones upslope of I-90 and shallow aquifers and wetlands on the terrace below I-90. Wolverine tracks were documented on Amabalis Mountain approximately 1 mile north of I-90 in March 1998.

What are the connectivity objectives at Hudson Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/grand fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snowpack. High structures would provide light under the structures to support plant life and increase the openness of the structure.
- Connect special soil type (K254) and the associated low-mobility species.
- Replace habitat connections for talus-associated species, wolverines, and possibly mountain goats.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Reconnect small wetlands and riparian habitats.
- Restore seepage and shallow groundwater flow paths that are currently intercepted by highway drainage systems and culverts.
- Improve channel functions at the east fork of Hudson Creek to allow natural channel development downslope of I-90.

Do the Hudson Creek design options meet the connectivity objectives?1

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<tbody>
<tr>
<td>A</td>
<td>240’ bridges 2 HCZs</td>
<td>⭐⭐⭐ Yes</td>
<td>Option A meets wildlife connectivity objectives by connecting talus-associated species and high-mobility species. This option meets hydrologic connectivity objectives.</td>
</tr>
<tr>
<td>B</td>
<td>120’ bridges 3 HCZs</td>
<td>No</td>
<td>Option B does not meet wildlife connectivity objectives because the bridge does not provide adequate space underneath for talus habitat, as well as open travel routes for high-mobility species. This option meets hydrologic connectivity objectives, although less than Option A.</td>
</tr>
<tr>
<td>C</td>
<td>24’ culvert 3 HCZs</td>
<td>No</td>
<td>Option C does not meet wildlife connectivity objectives because it does not meet minimum height requirements for high-mobility species, and only minimally meets requirements for low-mobility species associated with talus. Option does not meet hydrologic connectivity objectives for shallow subsurface flow and confines channel.</td>
</tr>
</tbody>
</table>

1 Stars indicate the MDT’s recommendation ranking; three stars = highest.
Summary of Easton Hill CEA

The Easton Hill CEA is located between MP 67.3 and MP 68.0, and is a broad, forested slope. I-90 is a widely divided highway in this CEA, with a forested median that is unique within the project area. The Easton Hill area is transitional between the dry forest types to the east and more mesic forests to the west. This area was identified as the most permeable area for late-successional associated species moving through the project area. Easton Hill has the highest concentration of elk collisions in the project area.

What are the connectivity objectives at Easton Hill?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the Douglas-fir/hemlock/grand fir species assemblage zone.
- Link late-successional associated species to roadless areas in an area of relatively high habitat connectivity.
- Connect special soil type (K254) and the associated low-mobility species.
- Significantly reduce wildlife-vehicle accidents in this high roadkill zone. This will require wildlife fencing around the crossing structures.
- Provide connections for species associated with aquatic habitat.
- Restore surface and subsurface flow paths connecting wetland areas bisected by the westbound lanes of I-90.

Do the Easton Hill design options meet the connectivity objectives?1

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<tbody>
<tr>
<td>A</td>
<td>120° bridge (EB and WB)</td>
<td>☀️☀️☀️ Yes</td>
<td>Option A bridges a pathway that currently receives a high level of ungulate use. Bridging this accustomed route would likely promote use of the crossing structure. Option facilitates east-west linkage to the Kachess River CEA (Option D) if the entire median could be fenced (our recommendation). Option provides the greatest hydrologic connectivity for Wetland AM.</td>
</tr>
<tr>
<td>B</td>
<td>Wildlife Overcrossing (EB and WB) 1 HCZ</td>
<td>☀️☀️ Yes</td>
<td>Option B provides unlimited openness (overcrossing) over lanes that are relatively tightly bundled, shortening the crossing. The overcrossing provides opportunities for buffering noise and light disturbance. Option aligns well with ridgeline travel paths, but field surveys suggest current level of use may not be as high as the Option A pathway. Linkage to Kachess River CEA is reduced; Wetland AM is connected via an HCZ.</td>
</tr>
<tr>
<td>C</td>
<td>Wildlife Overcrossing (WB) 120° bridge 1 HCZ</td>
<td>☀️ Lot crossing structures connected with a wide median—untested approach.</td>
<td></td>
</tr>
</tbody>
</table>

1 Stars indicate the MDT’s recommendation ranking; three stars = highest.
The Kachess River/Lake Easton CEA is located between MP 68.3 and MP 69.6, and the Kachess River watershed drains 40,632 acres. The Kachess River flows under I-90 via a 150-foot westbound bridge and a 99-foot eastbound bridge, and then empties into Lake Easton. This area lies within a north-south trending habitat corridor. Snow tracking and remote cameras indicate this is a high use CEA.

What are the connectivity objectives at Kachess River?

- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.
- Provide passage for fish and other aquatic organisms moving throughout the river system.
- Minimize negative impacts on the small wetland in the median of I-90 west of the Kachess River bridges.
- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/grand fir species assemblage.
- Link late-successional associated species to roadless areas in an area of relatively high habitat connectivity.

Do the Kachess River/Lake Easton design options meet the connectivity objectives?1

<table>
<thead>
<tr>
<th>Design Option</th>
<th>Description</th>
<th>Meets Objectives?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>120' bridges – Replace existing county bridges</td>
<td>No</td>
<td>Option A does not meet connectivity requirements because of nearby private development, which greatly reduces habitat effectiveness. Provides hydrologic connectivity at Kachess River.</td>
</tr>
<tr>
<td>B</td>
<td>Widen existing county bridges</td>
<td>No</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>C</td>
<td>Widen existing county bridges</td>
<td>No</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>D</td>
<td>Wildlife overcrossings (EB and WB) - west of county bridge Widen existing county bridges</td>
<td>★★</td>
<td>★★★</td>
</tr>
</tbody>
</table>

1 Stars indicate the MDT’s recommendation ranking; three stars = highest.
Chapter One

Introduction

What is the purpose of this recommendation package?

This Mitigation Development Team (MDT) Recommendation Package contains mitigation strategies, performance standards, and best management practices to guide development of ecological and hydrologic connectivity improvements for the I-90 Snoqualmie Pass East Project. This recommendation package represents the current state of scientific knowledge for this project within the project corridor. This recommendation package includes the range of design options developed by the Washington State Department of Transportation (WSDOT), and discusses whether or not the current design options would be expected to meet the project purpose and need for ecological connectivity, as evaluated by the MDT.

What do we know about the project area?

The I-90 Snoqualmie Pass East project spans the area from Hyak, near the crest of the pass, eastward to the town of Easton (Exhibit 1-1), with elevations ranging from 3,000 feet at Hyak, to 2,000 feet at Easton. The mountainous topography surrounding the project area creates a substantial rain-shadow effect, with precipitation ranging from 140 inches a year at the western end of the project area to 50 inches at Easton. This creates a significant change in vegetation and wildlife communities from west to east.

The I-90 corridor through the Snoqualmie Pass area is positioned within the Wenatchee National Forest and links a number of important wilderness areas and national parks, which provide refuge for wildlife. Numerous studies have identified the I-90 corridor as a critical area for demographic connectivity of species populations in the Pacific Northwest (Thomas et al. 1990; USDI 1992; USDA and USDI 1994; USDA and USDI 1997; USDA 1999). This area also represents the narrowest width, west to east, of public land in Washington’s Cascade Mountains (Exhibit 1-2).

Information about wildlife roadkill on I-90, landscape permeability, and wildlife use of culverts and habitat adjacent to I-90 indicates that the project area provides important linkages for the local movement of wildlife, as well as broader connectivity between the north and south Cascades (Singleton and Lehmkuhl 2000). The existing highway is a barrier to wildlife movement and improvements that provide ecological connectivity are needed to support linkages for multiple species over time (Singleton and Lehmkuhl 2000). Studies identified three significant north-south linkage zones within the I-90 corridor, each with its own distinct species assemblages (USDA and USDI 1997, Garvey-Darda and Worthington 2003). These areas include the Gold Creek Valley (forested habitat in the subalpine fir/mountain hemlock series), the area east of Keechelus dam...
Land Ownership, Wilderness, and National Parks in the Vicinity of the Project
Exhibit 1-2
Landscape permeability refers to the ability of organisms to move freely across the landscape for the purposes of accessing food resources, migrating to avoid severe weather, and dispersing young animals to unoccupied territories.

Why is ecological connectivity important?

Ecological connectivity across a landscape is important for animals because they need to access food resources, migrate to avoid severe weather, find mates, avoid natural events like wildfires, and disperse to maintain genetic fitness. Young animals also need to access unoccupied territories.

I-90 is built primarily on National Forest land. Past timber harvests of mature forest in the I-90 corridor have significantly altered habitats. Since the late 1990s, however, the area has been managed according to the Snoqualmie Pass Adaptive Management Area Plan (USFS and USDI 1997 [AMA Plan]). This plan requires protection of old-growth habitat, removal of portions of existing Forest Service roads, and management of recreation to facilitate species movement. In recent years, there have been substantial private and public land conservation efforts to protect old-growth forest, provide larger contiguous blocks of forested habitat, and facilitate habitat connectivity across the I-90 corridor through the acquisition of private land. The Cascades Conservation Partnership, the Mountains-to-Sound Greenway Trust, the U.S. Fish and Wildlife Service (USFWS), and the U.S. Forest Service (USFS) have invested over $100 million in these efforts during the last 5 years. These land purchases, along with the I-90 Land Exchange (USDA 1999), have added 75,000 acres (approximately 117 square miles) of land to the

Landscape features that affect species movement in the project corridor are not limited to the highway. Timber harvest, railroads, and substantial development in the Hyak and Easton vicinities affect the permeability of the area to wildlife. The Snoqualmie Pass area is easily accessible from Seattle urban areas, and there are increasing demands for recreational opportunities along the I-90 corridor. Historically, land ownership throughout the I-90 corridor has been a checkerboard of private and public lands (see Exhibit 1-2).
National Forest system adjacent to and within the I-90 Snoqualmie Pass East project area.

Providing ecological connectivity not only reduces the likelihood of demographic and genetic isolation of wildlife populations, but also has important safety and economic implications by reducing vehicle-wildlife collisions. Between 1991 and 2001, WSDOT counted 260 deer and elk killed on I-90 in the project area (Wagner pers. comm. 2005). The true amount of roadkill is certainly higher, as only animals that died on the highway were counted. Recording of roadkill can also be sporadic due to WSDOT maintenance personnel workloads or personnel changes. Additionally, animals that are struck and make it off the highway alive and later die are not counted. Furthermore, roadkill counts only include deer and elk. Occasionally, bear or mountain lion have been recorded, but other species such as coyote, small mammals, birds, and amphibians are not typically counted (Wagner pers. comm. 2005). In addition to the safety concerns, roadkill represents a loss of public wildlife resources for hunting and wildlife viewing.

Providing hydrologic connectivity is another critical component of the project. Stream crossing structures, such as undersized culverts, often create barriers to aquatic species migration and degrade habitat within channels, floodplains, and associated wetlands. Highway fill and drainage systems alter the hydrology of wetlands above and below the highway and contribute to water quality problems in the Yakima River. Improving water quality and restoring hydrologic elements that feed the upper Yakima River along the I-90 corridor are important for protecting public investments of over $120 million in salmon restoration in the Yakima Basin (NWPPC 2004). The proposed project would remove fish movement barriers at all fish-bearing stream crossings.

In 2002, the Washington State Legislature acknowledged the essential role of biological diversity in shaping the high quality of life enjoyed by citizens of and visitors to Washington State. In further recognition of this priority, new legislation, ESSB 6400, was passed directing the development of a framework for statewide biodiversity conservation. In light of this, providing connectivity

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1 To read the text of this legislation, go to http://www.leg.wa.gov/pub/billinfo/2001-02/senate/6400-6424/6400-s_hbr.pdf.
across I-90 is not only a proactive strategy to prevent species listings under the Endangered Species Act, but also protects functioning ecosystems that are essential for maintaining our diverse variety of wildlife—now and into the future.

**Why was the Mitigation Development Team created?**

The MDT was created as an advisory group to provide WSDOT and the project’s Interdisciplinary Team (IDT) with a mitigation strategy that would meet the needs of ecological connectivity in the I-90 Snoqualmie Pass East project. This multi-agency team consists of eight biologists and hydrologists from the USFS, USFWS, Washington State Department of Fish and Wildlife (WDFW), and WSDOT.

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**The MDT is tasked to make recommendations that respond to the following central question:**

Given what we know about animal movement and ecological connectivity requirements, and framing this knowledge within the context of a limited design/construction budget, where are the locations within the project area that provide the highest benefit-to-cost ratio and provide for a long-term solution to the issue of connectivity?

The goal of the MDT is to deliver a comprehensive strategy for ecological connectivity and establish a framework for mitigating unavoidable impacts on regulated natural resources consistent with best available science, state and federal laws, and ecosystem-based objectives of the Northwest Forest Plan (USDA and USDI 1994). This technical document will be used by WSDOT to develop feasibility and constructability requirements when designing structural improvements to this project area.

Our challenge is to integrate the best available information on ecological connectivity into a useful mitigation strategy. The IDT identified the need for ecological connectivity for this project as follows:

Previous studies have identified the need to correct ecological connectivity barriers created by the existing I-90 facility in the vicinity of the proposed project. Enhancing and improving the biological permeability of the roadway corridor will help achieve the goals of the Northwest Forest Plan for improving ecological connectivity within the Snoqualmie Pass Adaptive Management Area. Improving connectivity across the I-90 corridor will help reduce demographic and genetic isolation of species, and reduce the risks to wildlife and the public from vehicle/wildlife collisions. (Draft Environmental Impact Statement [WSDOT 2005])

WSDOT is presented with an opportunity for in-kind and atypical, out-of-kind mitigation measures for the purposes of improving motorist safety and promoting...
ecosystem health by reestablishing terrestrial and aquatic species and hydrologic connectivity. A highway design that enhances ecological connectivity would complement surrounding management and restoration efforts by federal and state agencies and conservation groups. Additionally, salmon recovery efforts in the upper Yakima Basin would be greatly enhanced by connecting stream habitat and protecting water quality in the project area.

**How did the MDT define ecological connectivity?**

The project’s purpose and need statement identified ecological connectivity as a project need. The MDT was tasked with determining what ecological functions are necessary to meet this project need. To accomplish this, we determined that a refined definition of ecological connectivity was necessary to better communicate the objectives of the project in a manner that would explain the overall goals at the landscape level. The MDT adopted the following definition:

**Ecological Connectivity**—The movement of organisms and the occurrence of ecological processes across an ecosystem over time. Intact ecosystems are structured by the dynamic processes that create a shifting mosaic of heterogeneous habitat patches. The ability of organisms to disperse freely through the mosaic is important to allow genetic exchange and recolonization of habitats, and to maintain functioning food webs. Genetic variability is a species’ insurance against localized or population level disturbances and ultimately improves an organism’s evolutionary potential. The ultimate outcome is natural sustaining populations across an ecosystem over time.

**Hydrologic Connectivity**—Maintaining natural flow paths that transmit water, sediment, and nutrients through watersheds, aquifers, and streams. Ecological connectivity cannot be sustained unless hydrologic processes function properly at a landscape and site scale.

Throughout this recommendation package we use “ecological connectivity” as the general term which incorporates both wildlife and hydrologic connectivity.

**What are the objectives of ecological connectivity?**

The I-90 Snoqualmie Pass East Project is unique among major transportation projects for including ecological connectivity in its “purpose and need” statement. The project is further distinguished for attempting to provide linkages for a multiple-species ecosystem. This recommendation package represents the next logical step in the ongoing development of strategies to reduce the ecological impact of highways, which is one element of the broader concept of "context sensitive design." Past projects have typically focused on particular species or groups of species that are considered to be particularly important in the area. Many examples of successful implementation of this approach have been
documented, and these success stories are the foundation upon which the I-90 strategy is built.

What sets the I-90 project apart is that it crosses an ecologically sensitive area within the 24-million-acre region covered by the Northwest Forest Plan. The Northwest Forest Plan is perhaps the most ambitious attempt ever made at implementing ecosystem management. In keeping with the ecosystem-based design and objectives of the Northwest Forest Plan, our broad connectivity goal for the highway is to reduce its fragmentation impacts on all species and key ecological processes in the project corridor. This umbrella covers species with extremely variable life histories and levels of mobility, ranging from gray wolves and Canada lynx at the high-mobility end of the spectrum, to amphibians and mollusks on the low-mobility end. Mitigation planning for a multiple-species ecosystem is not simple because wildlife species respond differently to crossing structures and the adjacent landscape features (Forman et al. 2003, p. 155).

The challenge associated with linking a complete ecosystem across a 6-lane highway is further increased by the fact that the relative mobility of numerous species of plants, fungi, and insects is simply not known. For these species, the only basis for designing linkages is reasoned biological intuition about the features that are most important in determining habitat suitability for these types of organisms. The I-90 project is an attempt to implement a sensitive design for ecosystem management in the forests of the Pacific Northwest.

**Ecological Connectivity Objectives**

The following list summarizes our broad objectives for achieving the above ecological connectivity goals across the entire project:

1. Move toward proper function and connection of hydrologic processes and aquatic and terrestrial habitats. Significantly improve the baseline condition of these processes and habitats.

2. Increase the likelihood of sustaining local and regional native populations by reducing direct mortality by improving highway permeability.

3. Increase opportunities for movement of organisms between populations in order to reduce the risks associated with demographic isolation and reduced genetic variability.

4. Reduce the need for intensive management of ecological resources in the project area by restoring self-sustaining, dynamic ecological processes and removing artificial constraints to ecosystem function.
What was the methodology and approach used for preparing this recommendation package?

The process used to develop this recommendation package is summarized in Exhibit 1-3. The initial steps included compiling and reviewing scientific information, conducting a baseline evaluation of the current conditions (Attachment 1), and developing ecological connectivity objectives (above). The MDT then developed two distinct sets of performance standards to meet the ecological connectivity objectives. The first set related to the design of connectivity structures (Connectivity Performance Standards) and the second set related to the management of Connectivity Emphasis Areas (CEA) and mitigation of highway impacts (Mitigation Performance Standards); these are discussed in detail in Chapter 2. The Connectivity Performance Standards were used to develop questions for the evaluation of proposed connectivity structures; these questions and CEA evaluations are found in Chapter 3. The combination of Connectivity Performance Standards and Mitigation Performance Standards serve as the foundation for a comprehensive mitigation strategy.

The team used information from numerous studies conducted in the project area on wildlife, fish, plants, fungi, wetlands, and hydrology (Garvey-Darda and Worthington 2003; Null and McQueary 2004; WSDOT 2002b and 2005a,b; Singleton and Lehmkuhl 2000).

After reviewing the site-specific information and relevant scientific literature, the MDT agreed that the location of hydrologic features (i.e., stream crossings) within the project corridor provided a logical nexus between ecosystem connectivity needs, requirements for protecting aquatic habitats, and design requirements. Stream crossings generally coincided with priority areas for ecological connectivity. Improvements there would provide multiple benefits. In addition, in several areas special structures were considered for terrestrial species connectivity separate from streams. We focused on 15 areas that we designated as CEAs (see Exhibit 1-1). Within several of these CEAs, a subset of additional areas referred to as Hydrologic Connectivity Zones (HCZ) occur, where the team recognized the importance of linking hydrologic features separate from the linkage of animal populations.

The MDT and the project designers used an iterative process to develop a variety of design approaches to improve connectivity in the highway designs in each of the CEAs. Performance standards were developed to establish general principles of design that could be applied across the entire project area. Chapter 3 summarizes our analysis of each CEA and HCZ. The summaries include the following information:

- A description of the CEA and its location within the project
- An evaluation of the design options developed by the I-90 design team to identify which options would meet the objectives for that CEA
I-90 Ecological Connectivity (EIS Purpose and Need Statement)

IDT Connectivity Information and Evaluation Needs

MDT Convened by IDT

Scientific Information (Existing Site-Specific and Technical Data Compiled) + Baseline Evaluation (MDT 2004 Report)

Ecological Connectivity Goals and Objectives

Identify Connectivity Emphasis Areas

Performance Standards

Performance Standards for Connectivity Structures

Connectivity Structures Evaluation Questions

Performance Standards for development of a Mitigation Strategy

Comprehensive Mitigation Strategy

Mitigation Development Team Recommendation Package

Mitigation Package (aquatic resources, revegetation, visual, reservoir and others to be done at future date)

MDT Methodology
Exhibit 1-3
Chapter 4 evaluates whether the combination of proposed structures would meet the project-wide connectivity objectives.

Chapter 5 summarizes the findings and recommendations of the MDT.

Who reviewed this recommendation package?

WSDOT brought together an external technical review panel of three independent scientists with experience in road ecology:

- Tony Clevenger, Ph.D., Wildlife Review, Western Transportation Institute, Montana State University
- Tom H. Martin, Jr., Hydrology Review, Battelle Institute/Pacific NW Lab
- Robert J. Pierce, Ph.D., Wetlands Review, Wetland Training Institute, Inc.

This technical review panel completed several sufficiency analyses to ensure that there were no omissions, errors, or information gaps in this recommendation package; they also provided suggestions for improvement. We considered all of their comments and have attempted either to incorporate them or to explain our rationale for holding alternate perspectives.

This recommendation package was also reviewed in detail by several WSDOT staff members, including the project manager and the leader of the design team, as well as one FHWA staff member who has extensive experience with wildlife crossing structures in roadways. Input from these reviewers has greatly increased the clarity, consistency, and logical integrity of this recommendation package.
Planning for Ecological Connectivity in the I-90 Corridor
Chapter Two Planning for Ecological Connectivity in the I-90 Corridor

Introduction

This chapter provides the conceptual foundation underlying our evaluation of how the proposed I-90 project will affect ecological connectivity. Our approach to laying this foundation is to describe what is known about how highways impact wildlife and hydrology, and to use this background to specify “performance standards” for the proposed project that will minimize the severity of these impacts.

We begin by defining terms and our vision of the desired environmental condition in the project area. We go on to discuss how different organisms living in the area vary in their ability to move, and how this variation affects both their vulnerability to being killed on the highway and their sensitivity to habitat fragmentation. Similarly, we describe hydrologic processes, habitats that depend on these processes, and how highways typically impact these processes and habitats.

Having described typical highway impacts on wildlife and hydrology, we go on to describe how impacts can be minimized through habitat protection, excluding wildlife from the roadway, and building well located and designed wildlife crossing structures. For these topics, we provide “performance standards” that would increase the likelihood of achieving our objectives for wildlife and hydrologic connectivity. One of the primary purposes of this chapter is to provide the scientific foundation that supports each of our performance standards. These performance standards are the basis for our evaluation of the crossing structure design options. This evaluation is presented in the next chapter.

Why is ecological connectivity important for this project?

Connectivity is part of a healthy ecosystem.

Our environment provides many functions and values upon which natural systems and human systems depend. Many of these functions rely on natural habitats. In considering this project, MDT focused on several easily identified ecological processes:

- Hydrologic routing through ground and surface water flow paths of a watershed, which accommodates floods, supplies clean water for beneficial uses, and maintains stream baseflows.
- Support of natural plant and animal populations, which maintain ecological diversity and guard against extirpation or extinction.
Refuge habitat for resident and transient fish and wildlife populations, which helps individual animals survive and ultimately benefits populations.

Connectivity helps maintain ecological processes in a natural state. Improving hydrologic flow and aquatic connectivity in the I-90 corridor would restore some of the ecological processes necessary for a healthy ecosystem, such as nutrient cycling, waste treatment, and food production. In addition, providing wildlife passage and habitat would promote gene flow and provide more space for resident and transient populations. Connectivity helps support sustainable populations of plants and animals by reducing isolation that can contribute to local extirpation/extinction if isolated populations become low.

The quality of the natural ecosystem has an effect on human health and well-being. By maintaining the natural ecosystem, we avoid getting to the crisis point where irretrievable losses occur or extreme measures are needed for species or resource protection.

**The I-90 highway corridor has a direct effect on ecological connectivity.**

The highway physically bisects a variety of important terrestrial and aquatic habitats, as well as being a significant cause of mortality for many species. The I-90 corridor has altered numerous ecological processes such as hydrologic flows and nutrient cycling. The roadway has also been a vector for introduction of non-native plant species, which affects the amount of habitat available for native populations of plants and wildlife.

Current traffic volumes probably discourage animals from attempting to cross the lanes, and present a high risk of collision when they do attempt it. Average daily traffic volumes currently exceed 27,000 vehicles per day, with busy weekend traffic being as high as 52,000 vehicles per day (WSDOT). When these traffic volumes are averaged over the course of the day, a vehicle passes a stationary point every 3.2 seconds, or 1.6 seconds on weekends. Even high-mobility animals that are fleet of foot currently have a difficult time crossing the highway,
and traffic volumes are expected to increase over time. Singleton and Lehmkuhl (2000) found that some species of wildlife are currently using existing culverts and bridges along the I-90 corridor in this area, but many other animals are probably unable to cross. The highway is currently a nearly impenetrable barrier to many of the smaller, low-mobility species.

Increased connectivity in the I-90 corridor would support the conservation of federally listed endangered species such as gray wolves and grizzly bears. Gray wolf and grizzly bear are found in the North Cascades and British Columbia. Suitable habitat exists for both species south of I-90, and there have been isolated sightings in the William O. Douglas Wilderness Area and the Oak Creek Wildlife Area, south of I-90.

**What is the desired ecological condition?**

The desired ecological condition is to have free passage north and south of I-90 for all terrestrial and aquatic organisms and natural flow of surface and ground water along the entire corridor. While this goal may never be fully achieved, current conditions can be improved by decreasing the risk of road mortality, genetic isolation, and subsequent extinction of some populations of wildlife species.

Restoring hydrologic connectivity would improve water delivery to the Upper Yakima River system. Seeps and springs along the north and east sides of I-90 probably historically provided cold water upwelling within the Yakima River, providing habitat for salmonids. In addition, reconnecting wetlands would result in an improvement in water quality and an exchange of nutrients among wetland and river habitats.

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration International 2004). For this project, ecological restoration is defined as assisting the recovery of ecological connectivity across the I-90 project area. This includes connecting populations, linking diverse habitats to facilitate dispersal and migration, and improving continuity of ecological processes, such as the natural movement of water across the landscape, the transport of sediment, and the movement of large woody debris by streams. It does not mean returning the transportation corridor to a pristine condition.

Overall, the desired ecological condition is to provide long-term sustainability of populations and to improve ecosystem processes that have been disturbed by the highway.
How do various species move across the landscape and what do they need to move across I-90?

The MDT used a multi-species approach to evaluate the ecological connectivity needs in the area of this project. The MDT sought to provide connectivity for the wide assortment of species that occur in the area, not just the common ones or those that present the greatest risk for vehicle collisions.

The MDT grouped species as high-mobility, low-mobility, and aquatic species. The intent was to keep in mind that different species have different mobility needs. These are general conceptual groups for thinking about the vagility of the species. Many species do not fit clearly into one category or another.

High-Mobility Species

High-mobility animals include a number of familiar species that are often the first that come to mind when we think of wildlife crossing roads. These animals all share the need to move across the landscape for several miles or more as part of meeting their ordinary biological needs.

Exhibit 2-1 lists high-mobility species that may be found in the project area, along with their expected range of movement.

In very general terms, this group includes larger animals such as deer, elk, bear, wolf, wolverine, and mountain lion. These are wide-ranging species where individuals occupy large home ranges. For example, black bears are highly mobile and readily disperse hundreds of miles across many types of habitats; a single bear may use a huge area. Studies in northern Washington document individual black bears having territories up to 13,000 acres (Poelker and Hartwell 1973). High-mobility species may have seasonal movement patterns (such as elk moving to lower elevations in winter), or travel widely to forage over a range of habitats (such as bear feeding on different plants as they ripen at different elevations). High-mobility species also include many of the top predators (such as mountain lion, bobcat, and wolverine) that can cover a large amount of ground in search of prey, some of which are also high-mobility species. Considering high-mobility species also includes the dispersal of young, which for many species requires movement out of their natal areas to establish new territories.
### Examples of High-Mobility Species

**Exhibit 2-1**

<table>
<thead>
<tr>
<th>Mammal Species</th>
<th>Home Range/Dispersal Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marten</td>
<td>A large but typical male home range is about 6 square miles (see Clark et al. 1987). Home ranges of males ranged from 2,500 to 5,000 acres in Minnesota (Mech and Rogers 1977); male home ranges in Montana were considerably smaller, ranging from 200 to 650 acres (Hawley and Newby 1957). Dispersal likely extends many miles (Small et al. 2003, Bull and Heater 2001, Buskirk and Zielinski 1997).</td>
</tr>
<tr>
<td>Long-tailed weasel</td>
<td>Male home ranges are normally 25 to 60 acres, but increase to 200 to 400 acres when prey becomes scarce (Sheffield, in Wilson and Ruff 1999). Female home ranges are smaller and are included within male home ranges. As in most animals, dispersal likely is much greater than a small home range might suggest.</td>
</tr>
<tr>
<td>Raccoon</td>
<td>Raccoons are highly mobile and may have home ranges that average as large as 6,300 acres (range 1,600 to 12,200 acres) for males in North Dakota (Fritzell 1978). In other areas, movements may be more limited: mean home range sizes for males were 500 acres in Michigan (Stuewer 1943) and 160 acres on St. Catherine's Island, Georgia (Lotze and Lotze 1979) (see also Lotze and Anderson 1981). Raccoons have been reported moving distances of up to at least 160 miles (see Lotze and Anderson 1981).</td>
</tr>
<tr>
<td>Grizzly bear</td>
<td>Home range sizes of grizzly bears tend to be very large and are dependent on an individual's size and food requirements. Males can range over areas that are from 540 to 1,450 square miles in size. Females range over areas that are from 110 to 341 square miles (Servheen 1983). Grizzlies are highly mobile and readily disperse hundreds of kilometers across many types of habitats. Populations and metapopulations tend to encompass huge areas (Craighead 1976, Pearson 1975, Proctor et al. 2004).</td>
</tr>
</tbody>
</table>
Some of these species may use habitat next to the highway as part of their regular home ranges. This is evidenced in recent studies of radio-collared mountain lion in the project area (Koehler pers. comm. 2005). Others (such as grizzly bear) would tend to only travel through the project area.

Some high-mobility species like mule deer and elk (members of a group called ungulates) are common in the project area. Others, like gray wolf, grizzly bear, and wolverine, are rare, at-risk species that may be present at very low densities but are the focus of protection and recovery efforts for the future.

The approach of this team for assessing connectivity structures has been to begin with a focus on the needs of the high-mobility species. There are several reasons:

- The travel patterns for high-mobility species are better known than the travel patterns for low-mobility species.
- Providing good connectivity for high-mobility species is likely to also benefit many low-mobility species in many cases.
- This group covers larger animals that present a greater safety concern for vehicular collisions.
- This group includes species that are plentiful and managed as game as well as those protected for their rarity.

To support connectivity for these species, the MDT evaluated data on known wildlife activity in the area, including tracking studies, deer and elk roadkill records, and local knowledge of wildlife sightings. The MDT also considered habitat type, topography, and landscape context to identify likely focus areas for animal movement.

In assessing the potential function of crossing structure designs, the MDT considered the alignment of the structure with topography and landforms likely to encourage animal movement, the habitat present adjacent to the structure, and the overall size and configuration of the structure. For most species, the more open-appearing the structure, the more likely it is to be used. In general, a 16-foot minimum clearance (to provide 12 feet of clearance over the typical 4-foot snow depth) was set for undercrossings. For a discussion of average peak-winter snow depths in the project area, see page 2-43. A bridge with a width of at least 120 feet was considered desirable, both for providing openness as well as to help establish vegetation in and around the structures to provide more natural cover for animals. This width is based on current research on effective crossing structures.
Low-Mobility Species

Small mammals, amphibians, reptiles, and invertebrate species are considered to have low vagility. These low-mobility species have small body sizes, small home ranges, and short dispersal distances. They also tend to be more sensitive to habitat fragmentation and microclimate changes within their environment. Exhibit 2-2 lists low-mobility species that may be found in the project area, along with their expected range of movement.

Small Mammals

Examples of small mammals in the project area include shrews, voles, moles, gophers, chipmunks, squirrels, rabbits, pikas, woodrats, and mice, all of which have relatively limited mobility (see Attachment 2 for list of species). Small mammals have relatively small home ranges and dispersal distances. A summary of available dispersal literature (Sutherland et al. 2000) found the following maximum natal dispersal distances: pikas (*Ochotona princeps*) .25 mile (Peacock and Smith 1997), shrews (*Sorex araneus*) .54 mile (Hanski et al. 1991; Peltonen and Hanski 1991), moles (*Scapanus townsendii*) 0.53 mile, gophers (*Thomomys bottae*) 0.19 mile (Daly and Patton 1990), deer mouse (*Peromyscus maniculatus*) 0.62 mile (Dice and Howard 1951), and voles (*Microtus spp.*) between .03 and .62 mile depending on species (Sandell et al. 1990; Boyce and Boyce 1988, McGuire et al. 1993; Steen 1994; Mihok et al. 1988; Lambin 1994; Wolff and Lidicker 1980).

Reptiles

Reptiles in the project area include lizards and snakes (see Attachment 2 for list of species). Although most snakes have the ability to move approximately half a mile in suitable habitat, the existing I-90 highway is probably a significant barrier to their movement. Snakes are frequently killed trying to cross busy highways, and rivers, lakes, ponds, and deep marsh habitats may also limit the movement of terrestrial snake species (NatureServe 2005). Limited data exist on snake species found in the project area. Available data on other species indicate that most home ranges are less than 61 acres; large colubrids, such as king snakes, range from 7 to 555 acres (NatureServe 2005). In an extensive radio-tracking survey, Blouin-Demers and Weatherhead (2002) found that the black rat snake had an average home range of approximately 45 acres.

Lizards generally have much smaller home ranges than snakes. For example, in Northern alligator lizards, the average home range is about 1 acre in adult males and one-third of a mile in juveniles (Fitch 1989).
### Examples of Low-Mobility Species

#### Exhibit 2-2

<table>
<thead>
<tr>
<th>Species</th>
<th>Home Range/Dispersal Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Invertebrates</strong></td>
<td></td>
</tr>
<tr>
<td>Mollusks</td>
<td>Factors influencing distribution of terrestrial snail species are difficult to identify and are not known for most species. Factors influencing distribution may in some cases be imperceptible to researchers (Cordiero 2003, NatureServe 2005). One study by Popov and Kramarenko (2004) indicates that land snails of the genus <em>Xeropicta</em> disperse at a rate of 9.85 feet per day. Additional research by Parmakis and Mylonas (2004) in Greece indicate that movement in two species of the genus <em>Mastus</em> averaged between 1.6 and 3.2 feet per month. Frest and Johannes (1995) stated that mature aquatic freshwater mollusks were “functionally sessile” (immobile), indicating that movement is probably extremely limited.</td>
</tr>
<tr>
<td><strong>Amphibians</strong></td>
<td></td>
</tr>
<tr>
<td>Ensatina</td>
<td>Staub et al. (1995) found the maximum dispersal distance for Ensatina was 394 feet and 199 feet for males and females, respectively.</td>
</tr>
<tr>
<td>Pacific giant salamander</td>
<td>Metamorphosed adults readily traverse natural and seminatural upland habitats during wet weather. Pacific giant salamander is very rarely found in the metamorphosed stage and is unlikely to travel more than a few feet from a stream or lake edge. Ferguson (1998) found that larvae are relatively sedentary, with the majority of individuals moving less than 55 yards between July and October.</td>
</tr>
<tr>
<td>Rough-skinned newt</td>
<td>May cross highly disturbed land, such as the cleared and bedded soils of some silvicultural sites. Individuals may move more than 875 yards from breeding ponds to terrestrial home ranges.</td>
</tr>
<tr>
<td><strong>Reptiles</strong></td>
<td></td>
</tr>
<tr>
<td>Northwestern garter snake</td>
<td>Available information on movements of colubrid snakes is limited to a small minority of species. These data indicate that nearly all species have home ranges smaller or much smaller than 60 acres (e.g., less than 3 hectares for <em>Pituophis catenifer</em> in California, Rodriguez-Robles 2003), with some up to about 185 acres (<em>Heterodon platirhinos</em>, average 125 acres, Plummer and Mills 2000), and the largest up to 555 acres in the biggest colubrids (<em>Drymarchon corais</em>, summer mean 125 to 250 acres, USFWS 1998).</td>
</tr>
</tbody>
</table>
Examples of Low-Mobility Species
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<tr>
<td><strong>Mammals</strong></td>
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</tr>
<tr>
<td>Pika</td>
<td>Male and female territories average the same size. Reported home ranges: 0.7 to 1.2 acres (Barash 1973); and mean 0.6 acre, range less than 1 acre (Kawamichi 1976). Juveniles tend to stay on natal home range or an adjacent one. Adult mortality 37 to 56% per year. Home ranges are small (Barash 1973, Kawamichi 1976), but dispersal can be fairly extensive. Peacock (1997) reported one observed 1.2-mile-wide dispersal between talus patches per year, and Hafner and Sullivan (1995) found that pika metapopulations are separated by 6 to 62 miles (maximum dispersal for an individual pika estimated at 6 to 12 miles). Suitable habitat includes talus; unsuitable habitat includes all other terrestrial habitats.</td>
</tr>
<tr>
<td>Snowshoe hare</td>
<td>Home range size varies with location and season; most studies indicate a home range size averaging 12 to 49 acres (Handley 1991). Male ranges average larger than those of females. In Yukon Territory, Canada, 18 natal dispersal distances ranged from 25 yards to more than 10 miles (all but two were less than 2 miles) (Gillis and Krebs 1999). Jackrabbits and hares are highly mobile and warrant large separation distances for suitable habitat. Dispersal not uncommonly extends several miles and sometimes tens of miles. Snowshoe hares may move up to 5 miles when food is scarce (Banfield 1974).</td>
</tr>
<tr>
<td>Townsend's chipmunk</td>
<td>Home ranges generally small, 0.5 to 10 acres (Broadbooks 1970, Sheppard 1972, Gashwiler 1965, Storer et al. 1944, Roberts 1962, Brown 1971, Eliot 1978, Wadsworth 1972). However, dispersal movements may extend to at least 0.5 mile.</td>
</tr>
</tbody>
</table>

**Ranid** refers to true frogs, which are usually semiaquatic web-footed amphibians that have smooth moist skin and long hind legs and eat insects.

**Amphibians**

Amphibians in the project area include frogs and salamanders with biphasic life histories (i.e., aquatic larval phase and terrestrial adult phase) as well as *Plethodontid* salamanders, which are strictly terrestrial (see Attachment 2 for list of species).

Ranid frogs (e.g., Cascades frog) vary in habitat use, but even the most aquatic species may cross upland habitat when conditions are suitable (Pope and Matthews 2001); natural and semi-natural upland habitat generally does not constitute a barrier. Unsuitable habitat for ranid frog species would be upland habitat that is devoid or nearly devoid of wetlands, streams, ponds, or lakes. Bodies of water dominated by predatory fishes may be barriers to some species.

Western toad

In the Shenandoah Mountains, data for R. sylvatica indicated that ponds separated by a distance greater than about 3,000 feet would experience little gene flow among them (Berven and Grudzien 1991). In contrast, there was gene flow among populations in Minnesota, even at distances greater than several miles (Squire and Newman 2002). However, the sizes and locations of the samples examined were small, and the genetic patterns do not necessarily reflect movement distances and may be species specific.

The terrestrial Plethodontid salamanders, such as Ensatina and Larch Mountain salamander, are considered less vagile. Studies of some log-associates found movement of only a few feet over seasons to years (Olson et al. 2001).

Mollusks

Little research has been done on home range and dispersal rates of land snails and slugs. One study by Popov and Kramarenko (2004) indicates that land snails of the genus Xeropicta disperse at a rate of 9.85 feet per day. Additional research by Parmakelis and Mylonas (2004) in Greece indicate that movement in two species of the genus Mastus averaged between 1.6 and 3.2 feet per month. Frest and Johannes (1995) stated that mature aquatic freshwater mollusks were “functionally sessile” (immobile), indicating that movement is probably extremely limited. However, aquatic mollusks have a greater ability for dispersal than terrestrial mollusks because of their closer association with water and opportunity to be carried by flow.

Crossing Structures for Low-Mobility Species

Crossing structures can be made more hospitable for low-mobility species by providing suitable habitat within the structures. Adding habitat elements such as coarse woody debris and legacy structures within the crossing structures would provide numerous benefits, including:

- Addition of organic matter to the soil
- Habitat for decomposer organisms
- Moisture retention through dry periods
- Habitat for ectomycorrhizal roots and associated soil organisms
Aquatic Species

A very important finding of the last 10 years is the importance of salmon to the overall functioning of ecosystems in the Pacific Northwest (Cederholm et al. 2000; Mathewson et al. 2003; Darimont and Reimchen 2002).

Although anadromous salmonid species cannot currently pass upstream of Keechelus Dam, restoring fish passage would return crucial nutrient cycling to the ecosystem. In the Pacific Northwest, Cederholm and others (2000) found that 138 wildlife species have a positive relationship with salmon. Marine-derived nutrients such as nitrogen are essential to plant growth in many terrestrial forests in the Pacific Northwest (Mathewson et al. 2003). Anadromous salmonids could access streams below the dam. For streams feeding into Keechelus Lake above the dam, resident fish and other aquatic species need to move within streams and between the lake and stream habitats.

Aquatic connectivity is essential for healthy watersheds. Restoring habitat accessibility to aquatic species provides an additional nutrient and food source to forest ecosystems. In addition, restoring habitat accessibility helps return nutrients to many streams within the I-90 Snoqualmie Pass East corridor. Healthy riparian forests contribute to nutrient and material exchanges between the aquatic and terrestrial systems (Naiman et al. 1992).

Many of the existing stream crossings in the project area are not passable for fish and other aquatic species. Access to habitat on the other side of I-90 is blocked and the opportunity for nutrient cycling and food chain support is lost. Removal of these barriers and replacement with crossings that provide a natural stream channel condition will restore connectivity for many species.

In addition to fish passage barriers associated with I-90 crossings, numerous other barriers to fish movement are present near the project area. These barriers are described in detail in the Aquatic Discipline Report (WSDOT 2002) and in Chapter 3 of this recommendation package, in which we describe the conditions in each CEA. Barriers in the project area include Keechelus Dam, which allows limited downstream movement of entrained fish but no upstream movement, and numerous natural and man-made features.
Performance Standards

Throughout the remainder of this chapter, most sections contain a short list of performance standards. Each performance standard in those lists is derived from the information presented in that section. For example, the performance standards that are listed immediately below are derived from the preceding information about how different types of organisms in the project area inhabit and move across the landscape. Our brief reviews of existing literature presented in each section provide the scientific basis for the listed performance standards. We developed these performance standards primarily to increase the likelihood that crossing structures designed for this project would achieve our multi-species connectivity objectives. These performance standards are also the basis of our evaluation of the likely performance of proposed designs for crossing structures (Chapter 3). For a complete list of performance standards, see Attachment 3.

- **Connectivity Performance Standard 1.1** – At a minimum, wetlands, riparian habitats, floodplains, streams, upland forests, and unique habitats, such as talus, should receive primary attention when assessing existing conditions and developing recommendations for improvements to ecological and hydrologic connectivity.

- **Connectivity Performance Standard 1.3** – Design wildlife crossing structures to accommodate aquatic, riparian, and terrestrial habitat components.

- **Connectivity Performance Standard 3.1** – Site crossings in areas with high landscape permeability; locate crossings that provide connectivity for both high- and low-mobility species within the three “linkage zones” associated with the mountain hemlock/subalpine fir, western hemlock/Pacific silver fir, and grand fir/Douglas-fir plant associations.

- **Connectivity Performance Standard 3.10** – Restore connectivity between unique habitats (e.g., talus) and old growth forests bisected by the existing road prism.

- **Connectivity Performance Standard 3.11** – Accommodate both high- and low-mobility species dispersal in high-priority CEAs (Gold, Price/Noble, Bonnie, Swamp, Toll, Hudson, Easton, and Kachess).

- **Connectivity Performance Standard 3.12** – Locate crossing structures to maximize connectivity of different habitats within each CEA. In bridges of 120 feet or less, use vertical walls within the structure to maximize habitats connected.

- **Connectivity Performance Standard 3.13** – Maximize continuity of native soils adjacent to and within bridges and on wildlife overpass structures.

- **Connectivity Performance Standard 3.16** – Design crossing structures to allow for future species redistribution and recolonization due to improved
habitats, recovery plans, or re-introductions (e.g., grizzly bear, wolf, lynx, fisher).

**What is needed for hydrologic connectivity?**

Hydrologic connectivity is maintaining natural flow paths that transmit water, sediment, and nutrients to and through watersheds, aquifers, and streams. The health of terrestrial, aquatic, and riparian ecosystems depends on complex interactions between surface runoff, groundwater flow, and stream channel processes. Ecological connectivity cannot be sustained unless hydrologic processes function properly at landscape and site scales.

Both legal requirements and a strong scientific rationale dictate that we address hydrologic connectivity in this recommendation package. National Forest management regulations and land management objectives, standards, and guidelines (Attachment 4) are in place to ensure that actions taken within National Forests are consistent with National Forest land and resource management plans. Hydrologic connectivity is an important element of USFS’s Aquatic Conservation Strategy and riparian reserve management. Riparian reserves are areas along streams, lakes, ponds, and wetlands that USFS has designated as areas of primary management emphasis for riparian-dependent species and hydrologic features. Riparian reserves are intended to serve as connectivity corridors among late-successional forest reserves.

The USFS has determined that the I-90 project has potential to affect the attainment of Aquatic Conservation Strategy objectives for hydrologic connectivity. Because of this, it is necessary to evaluate the effects of the I-90 project design on hydrologic connectivity in the context of the Aquatic Conservation Strategy’s standards and guidelines (see Attachment 4). Further, the existing highway corridor was constructed at a time when regulatory requirements were few and the importance of hydrologic connectivity was less clearly understood. These factors resulted in the construction of a highway prism that altered the natural aboveground and belowground movement of water in key areas. With our growing scientific understanding of water movement and our focus on restoring ecological functions and connections, our ecological connectivity objectives could not be met without addressing hydrologic connectivity.

**Hydrologic Connectivity**

Our objective for restoring hydrologic connectivity is to move toward proper functioning of hydrologic processes (see Objective #4 on page 1-8). In riparian and wetland areas, proper hydrologic function means providing adequate vegetation, landform, and large woody debris (BLM 1993) to achieve the following:

- Dissipate stream energy during high flows
- Filter sediment and capture bedload
- Improve floodwater retention and groundwater recharge
- Develop root masses that stabilize streambanks
- Develop diverse pond and channel characteristics
- Provide lower water temperature conditions
- Provide for continuity between surface and subsurface flow beneath the highway at low-gradient wetlands or areas of unconfined surface flow

These are needed to provide the aquatic habitat, flow characteristics, and water quality necessary to support fish production, wetland habitat, waterfowl breeding, and overall biodiversity.

Proper hydrologic function also means maintaining natural mechanisms for delivering and routing water through the landscape. Much of the I-90 corridor occupies a transition from a steep hillslope environment to terraces and historic floodplains. Subsurface flow from these hillslopes replenishes wetlands and aquifers on stream valley floors. Seeps and shallow groundwater deliver cool water and nutrients to streams and wetlands, and are important sources of water for aquatic habitats during dry periods (Meyer et al. 2003; USDA 2003; Poole and Berman 2001).

**Highway Impacts on Hydrologic Connectivity**

Roads have significantly altered natural hydrologic processes in the upper Yakima River valley. I-90 bisects numerous wetland complexes, limiting hydrologic connectivity between upslope wetlands and wetlands in the Yakima River floodplain (Null and McQueary 2004). Highway drainage systems channelize sheet flow and intercept seepage (U.S. Army Corps of Engineers 2002; HartCrowswer 2002). Flow concentration and interception of seepage by road prisms can cause erosion, excessive ponding, and road prism saturation (USFS 2000). Soil compaction and cut slopes reduce soil permeability and disrupt subsurface flow paths. This alters the hydrology of wetlands above and below the highway, and reduces recharge to shallow aquifers in the Yakima River valley. These hydrologic changes increase sediment delivery and water temperatures, and contribute to water quality problems in the Yakima River system (Tetra Tech, Inc. 2002).

Many of the existing stream crossing structures in the project area limit natural channel functions and create barriers to aquatic species migration (WSDOT 2002b). This reduces aquatic species diversity and disconnects populations. These structures also limit natural channel migration, resulting in simplified and degraded habitat in channels, floodplains, and associated wetlands (Washington State Department of Wildlife 2003; U.S. Army Corps of Engineers 2002; WSDOT 2002b). Bridge approaches in the project area are built on fill that has
eliminated wetland and riparian habitats on the floodplains. Creek channels have become deeply incised upstream of the highway, particularly where culverts drain through road prisms that cut into a wetland. Undersized culverts and bridges have concentrated flow and caused bank erosion and channel incision downstream of the highway (WSDOT 2002b).

Old highway design standards for stream crossing structures did not consider many of the factors that we now know are important in maintaining natural hydrologic functions. Structures that met the old standards often concentrate flow, resulting in bank erosion and channel incision downstream of the highway (WSDOT 2002b). Maintenance at these structures often requires channel excavation that artificially lowers the base level of the streambed and releases sediment into streams. Large concrete box culverts have altered the natural substrate of creek beds and their cross-sectional shape. The flow conditions in these culverts are wide, shallow, and fast, which present fish passage problems.

Water quality is also a concern for aquatic resources in the project area. High water temperatures, water pollution, and sediment impair water quality in many streams in the upper Yakima River basin. Tetra Tech (2002) found pollutants commonly associated with highway runoff in Coal Creek, Toll Creek, Swamp Creek, Rocky Run Creek, the Yakima River, and the Kachess River. Gold Creek and the Yakima River are on the Washington State 303(d) list of impaired waters for high water temperatures. The following impacts from I-90 contribute to these problems:

- Highway and Sno-park runoff carry pollutants and sediment into adjacent streams, lakes, and wetlands.
- Hydrologic and vegetative alterations increase water temperatures.
- Herbicides, winter traction sand, and de-icer chemicals may adversely affect aquatic resources.
- Ditch cleaning and other maintenance activities contribute sediment to streams.

Water quality impacts can be reduced by restoring natural hydrologic processes, improving stormwater management, and improving maintenance practices.

Performance Standards
For a complete list of performance standards, see Attachment 3.

- **Mitigation Performance Standard 1.8** – Where and when feasible, locate material sources (e.g., gravel mines) for the I-90 Snoqualmie Pass East project in areas outside the active geomorphic floodplains in the Yakima River Basin.

- **Mitigation Performance Standard 4.7** – Treat all stormwater runoff from the highway prior to discharge to streams and other water resources, using low impact development techniques, best management practices, and guidelines identified in the WSDOT *Highway Runoff Manual* and the WSDOT
Hydraulics Manual. Highway runoff should not be routed into drainage structures designed for hydrologic connectivity unless it has first been treated using natural or engineered dispersion.

- **Mitigation Performance Standard 4.8** – Establish special protocols for the application of herbicides, winter traction sand, and de-icer near streams and HCZs.

- **Mitigation Performance Standard 4.9** – Establish a spill response plan for HCZs and wildlife crossings.

- **Mitigation Performance Standard 5.4** – Develop and implement a monitoring plan to ensure that water quality is maintained and improved.

Providing hydrologic connectivity on National Forest lands adjacent to I-90 would improve hydrologic features and functions in the CEAs. To appropriately consider hydrologic connectivity, hydrologic scales must be considered, ranging from the smallest hydrologic features of seeps and springs to the largest features of rivers and floodplains draining fifth-field watersheds (20,000 acres and larger). Potential impacts from construction and operation of the I-90 project will extend over a period of decades on the temporal scale, while expanding across a spatial scale of nearly 15 miles of right-of-way, with potential downstream effects beyond the project boundary. In the project area, there is the potential to affect more than 12 streams and floodplains, 10 wetland complexes, and numerous seeps and springs.

**Hydrologic Connectivity Zones**

The MDT identified performance standards for stream crossing structures that would restore natural water, sediment, wood, and organism movement under the highway. We designated HCZs within each CEA where special structures are needed to maintain natural surface and subsurface flow paths. The HCZs link wetlands, shallow aquifers, and other important hydrologic features that are not always associated with stream crossings. We have also delineated HCZs where the highway bisects the following landscape features:

- Seepage zones that recharge downslope wetlands and shallow aquifers
- Alluvial fans where groundwater and shallow surface flow recharge wetlands
- Floodplain fringe on unconfined streams, adjacent slopes, and terraces
- Major wetland complexes

Seepage zones and alluvial fans were identified based on reconnaissance field surveys conducted by the MDT, as supplemented by geology maps, soils maps, and well logs (Ecology 2004). Maintaining seepage flow paths will help maintain summer stream base flows, cooler water temperatures, and nutrient balances in downstream aquatic ecosystems (Meyer et al. 2003; USDA 2003; Poole and Berman 2001). Wetlands were identified using the project wetland coverage developed by Null and McQueary (2004).
We have identified the general locations of HCZs using the available landscape-scale information. The exact locations and configuration of drainage structures in these zones will need to be refined during project design based on groundwater monitoring and flow analysis. A conceptual model of hydrologic processes in each CEA will be developed using topographic, geologic and soil maps, and ground and surface water elevations. Exhibits 2-3 and 2-4 illustrate two examples of structures that might be used at HCZs. The design shown in Exhibit 2-3 could be used to link low-gradient wetland habitats on either side of the highway. Open-bottomed culverts would allow surface and subsurface flow at multiple locations along the HCZ, as well as passage for small animals. The design in Exhibit 2-4 focuses on subsurface drainage, and might be appropriate in locations where the objective is to convey hillslope seepage to aquifer recharge areas and wetlands on the downslope side of the highway.
Performance Standards
For a complete list of performance standards, see Attachment 3.

- **Connectivity Performance Standard 1.2** – Improve hydrologic function and connections of stream channels, riparian areas, floodplains, wetland flow paths and hydroperiods, and groundwater/surface water interactions. Use WDFW stream simulation specifications in the design of the appropriate span for crossing structures.

- **Connectivity Performance Standard 1.7/Mitigation Performance Standard 1.7** – Use vertical walls or other measures to minimize filling of wetland habitats.

- **Connectivity Performance Standard 1.8/Mitigation Performance Standard 4.3** – Provide hydrologic connectivity structures that maintain
properly functioning conditions and restore natural surface and subsurface flow paths through the road prism at wetlands, seepage zones, and areas of unconfined surface flow. These structures should minimize artificial flow concentration and conversion of subsurface flow to surface flow.

- **Connectivity Performance Standard 1.9** – Provide continuous wetland habitat through the highway right-of-way where there is potential linkage to high-value wetlands. Restore natural topography, soil conditions, and wetland flow paths adjacent to and beneath connectivity structures intended to connect wetland habitats.

- **Connectivity Performance Standard 3.15** – At a minimum, provide stream crossings that meet WDFW stream simulation specifications to allow passage of fish and other aquatic organisms (WDFW 2003). Consider adding debris (large wood) and a terrestrial bench inside the culverts.

- **Connectivity Performance Standard 4.1/Mitigation Performance Standard 4.1** – Design all stream crossings to allow the natural movement of water, sediment, large wood, and debris flows through the road prism. Presidential Executive Order 11990 (May 24, 1977) mandates minimizing the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands. In addition, Governor Booth Gardner issued Executive Orders 89-10 and 90-04 to achieve no overall net loss in acreage and function of Washington's remaining wetlands base. Use WDFW stream simulation specifications in the design of the appropriate span for crossing structures.

- **Connectivity Performance Standard 4.2** – Span the portion of the active channel migration corridor of unconfined streams needed to restore floodplain, channel, and riparian functions.

- **Connectivity Performance Standard 4.3/Mitigation Performance Standard 4.2** – Provide multiple stream paths to accommodate channel migration on alluvial fans.

- **Connectivity Performance Standard 4.5/Mitigation Performance Standard 4.1** – Use vertical abutments or other methods to maximize the area of floodplain, riparian habitat, wetland, and unconfined flow beneath bridges and crossing structures, especially at shorter spans where fill slopes could encroach on and limit ecological functions under the structure. Presidential Executive Order 11990 (May 24, 1977) mandates minimizing the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands. In addition, Governor Booth Gardner issued Executive Orders 89-10 and 90-04 to achieve no overall net loss in acreage and function of Washington's remaining wetlands base. Use WDFW stream simulation specifications in the design of the appropriate span for crossing structures.
- **Connectivity Performance Standard 4.6** – Minimize fill on floodplains and flood-prone areas. Presidential Executive Order 11988 (May 24, 1977) mandates federally funded projects to minimize floodplain impacts.

- **Mitigation Performance Standard 1.3** – Improve hydrologic connections to the extent that project area stream channels, riparian areas, floodplains, wetland flow paths and hydroperiods, and groundwater/surface water interactions have moved or are moving to a properly functioning condition.

- **Mitigation Performance Standard 3.12** – Accommodate low-mobility species in crossings designed primarily for water passage when applicable.

- **Mitigation Performance Standard 4.5** – Design all bridge supports within the floodplain area to accommodate channel changes throughout the span.

- **Mitigation Performance Standard 4.6** – Avoid soil compaction in floodplains, areas with hydric soils, seepage zones, and groundwater recharge areas. Minimize soil compaction in construction areas outside of the road prism. When these areas are disturbed during construction, restore soil physical conditions (including infiltration rates, bulk density, organic ground cover, and vegetation) to pre-construction conditions.

- **Mitigation Performance Standard 4.11** – Recycle or remove all fill from abandoned segments of roadway.

- **Mitigation Performance Standard 5.1** – Establish and implement monitoring plans at each CEA to determine whether established performance standards for the project area are being met. When one or more performance standards for an individual CEA drop below average performance standards established for the project area, adaptive management procedures are triggered that determine the cause and develop and implement corrective actions.

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**What are the ecological connectivity considerations at the broad corridor level of the project?**

**Minimizing Habitat Impacts**

I-90 stretches across a biologically diverse section of the central Cascades. It leaves both a physical and “ecological” footprint upon the habitats it passes through. The physical and ecological footprints of the highway will expand due to both added lanes and the realignment of existing lanes for a safer and more efficient roadway.

The “ecological footprint” of the highway typically consists of an area 6 to 8 times the physical footprint of the highway. This is predominantly due to the effects of noise, air and water pollution, hydrologic impacts, barrier effects, lights, de-icer, other chemicals/spills, disruption effects (e.g., noise interfering with birds calling and amphibian chorus during breeding periods), and habitat fragmentation (Forman et al. 2003, Forman et al. 2000).
Expanding the highway will directly impact old growth forests, wetlands, streams, lakes, talus, and unique soil types. Furthermore, there will be multi-year (although temporary) impacts due to construction staging areas and the need to maintain a functioning highway during construction. Moreover, the highway is only one of the cumulative effects on these habitats throughout the corridor. Forestry, recreation, power line corridors, and dams have also altered these biologically diverse systems in the past, therefore making it even more critical that the highway’s impacts are minimized. To mitigate for the increased footprint of the highway and the associated loss of habitat from right-of-way acquisition, habitat should be purchased for conservation purposes surrounding the highway corridor. Restoration of habitat along the old highway corridor or borrow pits (such as Gold Creek Pond) could mitigate for expected future impacts. Habitat losses can be reduced by minimizing the highway “footprint” through the bundling of lanes (rather than separating lanes by a central median) and using vertical walls in elevated sections of highway (rather than fill slopes).

Highway noise is a significant impact to the habitat adjacent to I-90, and an especially important influence around wildlife crossing structures. The performance of wildlife crossing structures can be significantly reduced if highway noise is not mitigated. Forman et al. (2003) studied grassland bird habitat use around different-sized roadways, and found eastern meadowlark and bobolink did not use habitat within .75 mile of busy highways (25,000+ vehicles per day) for foraging or breeding. Clevenger (2002) found that quieter structures in Banff National Park had higher frequencies of wolf crossings. Noise reduction can be attained through construction of berms, walls, use of natural features, vegetation, or using quieter road surfaces.

Performance Standards
For a complete list of performance standards, see Attachment 3.

- **Connectivity Performance Standard 1.4** – Protect existing habitat, particularly old growth and late-successional habitat. Where habitat loss occurs, reserve all trees, large logs, and root wads to be used adjacent to and within crossing structures.

- **Connectivity Performance Standard 1.5** – Where feasible, reduce the highway “footprint” and loss of habitat by bundling lanes (keeping them together rather than separated by a central median).

- **Connectivity Performance Standard 1.6** – In areas with elevated sections of highway, utilize vertical walls rather than fill slopes to reduce the loss of habitats and the risks associated with noxious weed spread and treatment.

- **Mitigation Performance Standard 1.9** – Compensate for forest/habitat lost during construction by purchasing replacement forest/habitat of similar type, at the appropriate mitigation ratio, adjacent to the highway corridor. If possible, compensation should occur adjacent to highway crossing structures to improve their effectiveness.
Mitigation Performance Standard 1.10 – Compensate for wetlands impacts by using a combination of structural elements, restoring altered habitats adjacent to the highway, and possibly purchasing land to preserve existing wetlands.

Wildlife Exclusion

How do we know where to place fences?
Fencing locations are typically chosen based on roadkill information, placement of wildlife crossing structures, and landscape permeability. Wildlife crossing structures are significantly more effective if they are accompanied by fencing or other exclusion methods along the roadway to guide animals to the structures (Clevenger 2002, Jaeger and Fahrig 2004). In areas without crossing structures, fencing is recommended when traffic is so busy that animals almost never cross the road successfully. However, fences can be detrimental when there is a fair chance that animals will make successful over-surface crossings, or when animals need to migrate to access resources on both sides of the road (Jaeger and Fahrig 2004). I-90 currently averages 27,000 vehicles per day, with busy weekend traffic exceeding 52,000 vehicles per day. If averaged over the entire day, this translates to a vehicle every 3.2 seconds and 1.6 seconds, respectively—enough for the highway to be a virtual barrier for most species.

Although wildlife exclusion can prevent animal mortality due to vehicle-animal collisions, exclusion can also have other unintended impacts. These impacts can include increased barrier effects, fragmentation of populations, and predators using fences as prey traps. Gibeau and Heuer (1996) reported coyotes running bighorn sheep into fences which blocked the bighorn escape routes to nearby cliff habitat. Foster and Humphrey (1995) also report mountain lions and wolves running deer up against fences to facilitate kills.

Fences should be placed on adjacent frontage roads, where possible, such as on USFS Road 4832, which runs from Gold Creek to about milepost 58. This placement will minimize visual impacts, reduce impacts to fences from snow plowing, and facilitate maintenance of fences.

What types of fences are needed?
Excluding wildlife from roads can be accomplished in several ways using physical barriers such as fences, walls, natural barriers, and sometimes artificial boulder fields. Large mammals, such as deer, elk, bear, and mountain lion, require a 10- to 12-foot-tall, high-tensile strength wire fence and wooden or metal posts (Falk et al. 1978; Clevenger et al. 2001). These structures also work for medium-sized mammals such as coyote, bobcat, rabbits, and marten. Some areas may need buried fence, because animals such as coyotes or badgers will dig under the fence (Groot Bruinderick and Hazelbrook 1996). Fences placed in high snow load locations will need to be heavy duty and may require more maintenance. Fences that incorporate slats limit an animal’s visibility, and can help improve the animal’s perception that the fence is a barrier.
Excluding smaller animals such as mice or amphibians and reptiles is accomplished with short walls or steep embankments, in conjunction with large, medium, or small crossing structures (USDOT 2001, Jackson and Curtice 1998). Short walls are typically constructed of concrete and have a lip at the top to deter climbing animals such as salamanders. Amphibian and reptile barriers should be placed along and adjacent to wetland and stream habitats, whereas exclusion barriers for snakes and lizards will need to be located in upland areas adjacent to open habitat such as talus or dry upland slopes.

Placement of fences is extremely important, both to ensure their effectiveness and to not impede animal movements to critical winter range, breeding sites, or forage areas. Using natural barriers adjacent to the highway to limit animal movement can be a cost-effective method of controlling crossing locations. In areas where maintenance is difficult, rock walls or other semi-natural barriers can be constructed, and these structures are likely to minimize highway noise as well. Terminating a fence at a wildlife crossing and/or a natural barrier will increase its effectiveness.

How successful is fencing animals off the highway?

Fencing can be highly successful for the majority of medium to large mammal species. Fencing along the Trans-Canada Highway, in conjunction with animal crossing structures, has resulted in an 80 percent reduction in all wildlife roadkills, and greater than 90 percent reduction in roadkills for ungulate species (Clevenger et al. 2001). However, some species such as bears and mountain lions can climb over fences, and coyotes or badgers dig under fences (Sipes and Neff 2001, Gibeau and Heuer 1996, Clevenger et al. 2001). Therefore, some locations may require buried fence to prevent certain animals from entering the highway corridor.
If animals get onto the highway, how do we ensure they exit safely?

Animals that accidentally enter fenced sections of roadway must be provided one-way gates or ramps to exit (Reed et al. 1974, Parks Canada 2004). Studies have shown one-way exit ramps to be more effective than gates (Bissonett and Hammer 2000; Ludwig and Bremicker 1983).

What happens at the end of the fence?

The end of a fence can be a particularly troublesome spot for animal vehicle collisions. Clevenger (2002) found significantly higher wildlife-vehicle collisions near fence ends; however, there are several ways to minimize this effect. Improved lighting, lowered speed zones, signing, and directing the fence end away from the highway or toward a natural barrier have all been shown to be effective (Clevenger 2002). Ending a fence near a natural travel corridor will also help direct wildlife to a safe crossing area and reduce the potential for accidents. Installing boulder fields or riprap can also help discourage ungulate passage during the spring-fall period when snow is not present. Boulder fields may work in high snow areas, as the majority of deer and elk in the project area move to lower elevations during the winter. Fence ends that intersect road crossings can use cattle guards to minimize unwanted entry to the highway corridor; however, cattle guards are not always effective for all species (Clevenger et al. 2002).

How will we know if fencing is working?

Monitoring of pre- and post-construction roadkill and use of crossing structures will inform us of the effectiveness of fencing. Using adaptive management principles, modifications to fencing may be necessary to improve effectiveness. Research from Banff National Park indicates that animal use of crossing structures increases over time. Similarly, animals may learn where fences end, and new roadkill problems may appear. So, a fencing strategy will take monitoring and adjustments over time (Clevenger et al. 2002).

How do we minimize the visual impacts of fences?

There are a number of ways to minimize the visual impacts of fencing. Concealing fences through strategic placement outside the visual corridor is an effective strategy. However, when fences need to be placed within the visual corridor, aesthetics can be improved by constructing the fence out of painted materials to match the color of the background landscapes. Another visual tool is to use smaller fence posts, so as not to attract the eye to the fencing. Planting small shrubs or other vegetation in front of a fence will also help conceal its presence.
How expensive is fencing?
The cost of installing fencing in Canada ranged from 40,000 to 80,000 Canadian dollars per kilometer (USD ~$53,000 to $105,000 per mile) to fence both sides of the highway. Maintenance of fences is the key to effective exclusion over the long term (Parks Canada 2004). Maintenance costs would be somewhat offset through cost savings from reductions in WSDOT personnel removing animal carcasses.

What type of maintenance is needed on fences?
Fence maintenance and repair is vital in order to reduce wildlife-vehicle collisions. Long-distance fencing in mountainous terrain exposes these structures to falling trees, vehicle accidents, weather events (such as heavy snow loads), erosion, and possibly vandalism. In Norway, wildlife fencing has been designed to be used in high snow zones. Regular inspection of fence lines will be necessary to ensure their success, and a logbook of fence repairs should be kept to identify the source of the problem, locations, frequency, and types of repairs required. Fencing designs should be tested under the weather conditions the fence is expected to face prior to its permanent installation.

Performance Standards
For a complete list of performance standards, see Attachment 3.

- **Connectivity Performance Standard 2.1** – At a minimum, place connectivity structures in all areas of high wildlife activity/car-animal collisions.

- **Connectivity Performance Standard 2.2** – In areas with elevated sections of highway, utilize vertical walls rather than fill slopes to reduce access to roadway by animals.

- **Connectivity Performance Standard 2.3** – Discourage wildlife presence within the right-of-way by using salvage materials (from the project) and topographic features as barriers whenever possible, and by using fencing, walls, and other artificial barriers when needed.

- **Connectivity Performance Standard 2.4** – Install amphibian and reptile walls (short walls with a lip) along wetland and upland habitat areas frequented by these species.

- **Mitigation Performance Standard 2.1** – Post-project, substantially reduce large mammal mortality below baseline average annual mortality data.

- **Mitigation Performance Standard 2.2** – Install fencing, barrier walls, and escape ramps based on best available science.

- **Mitigation Performance Standard 2.3** – Inspect all fencing, barrier walls, and escape ramps annually (after snow melt) and maintain them to function properly.
Mitigation Performance Standard 2.4 – Use legacy structures (e.g., large logs, root wads), vegetation and other habitat features, and fencing to facilitate wildlife use of large crossing structures.

Mitigation Performance Standard 2.6 – Encourage use of crossing structures by wildlife by using wildlife exclusion structures such as fencing, rock walls, or other barriers along the highway to direct wildlife into crossing structures. Use topography and natural features as much as possible.

Mitigation Performance Standard 2.7 – Provide escape ramps (primarily) or one-way gates (only where ramps are not possible) for animals that accidentally enter the highway corridor.

Mitigation Performance Standard 2.8 – Provide increased lighting at fence ends and direct the end of the fence away from the highway in a “J” pattern where appropriate.

Mitigation Performance Standard 2.10 – Encourage use of wildlife crossing structures by baiting and cutting trails leading to crossing structures where appropriate.

Mitigation Performance Standard 2.11 – Inspect and maintain wildlife fences and walls a minimum of twice a year. Collaboratively develop a maintenance log and inspection schedule with WSDOT maintenance personnel.

Mitigation Performance Standard 5.2 – Develop and implement a monitoring plan to address wildlife exclusion methods. This plan will include systematic data collection of observations of animals that have either climbed over or gotten though the fence, fence ends, other potential openings, gaps, or deficiencies.

Vegetation Management

Managing vegetation along the highway corridor is necessary to improve highway safety, and is also critical to optimize the success of the wildlife crossing structures. Vegetation along the highway or in the median should be managed so as not to attract wildlife to the highway corridor; however, around CEAs, it is essential to manage the habitat at the approach to and within the crossing structures to function as designed for the site. Minimizing disturbance to existing vegetation during construction and maintenance will minimize invasion by weedy species and allow native species to flourish.

Invasive species are a significant economic and ecological concern as evidenced by studies that estimate invasive species are responsible for between $123 and $137 billion (U.S.) a year in economic losses (Hall 1999; Pimentel et al. 2000). Highway rights-of-way are often areas where native vegetation is altered and can provide corridors for invasive non-native species to spread to adjacent lands (FHWA 1998). Fill slopes adjacent to the highway result in increased risk of noxious weeds, which in turn result in increased use of herbicides to control

Vegetation Management
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The use of vertical walls (rather than fill slopes) in elevated sections of highway can minimize the amount of fill, noxious weed occurrence, and herbicide treatments. Restoration of native plant communities along the old alignment will help mitigate the impacts of the new highway and minimize the effects of maintenance and safety actions. See the What is the desired ecological condition? section for the definition of restoration as used in this recommendation package.

Legislation and direction for the control of invasive species comes from the Federal Noxious Weed Act of 1974, the Endangered Species Act of 1973, the National Environmental Policy Act of 1969, and a 1999 Presidential Executive Order on Invasive Species (#13112). Furthermore, the Federal Highway Administration has developed guidelines to prevent the introduction of new invasive species along highway corridors.

A successful vegetation management plan will:

- Prevent roadside invasion and dispersal of invasive non-native weeds.
- Minimize unnatural side slopes.
- Use native plants for ground cover to out-compete invasive species.
- Maintain critical native habitats and minimize roadside disturbance to prevent weed colonization (for example, vertical walls in elevated sections of roadway).
- Provide lower maintenance costs.
- Reduce surface runoff and improve infiltration and water quality.
- Reduce economic and ecological costs associated with non-native plants.
- Reduce chemical weed control.
- Reflect the natural beauty and biodiversity of the region.

Performance Standards

For a complete list of performance standards, see Attachment 3.

- **Connectivity Performance Standard 1.6** – In areas with elevated sections of highway, utilize vertical walls rather than fill slopes to reduce the loss of habitats and the risks associated with noxious weed spread and treatment.

- **Connectivity Performance Standard 4.7** – Design alternatives with minimal clearing widths to reduce impacts to existing vegetation.

- **Mitigation Performance Standard 4.12** – Minimize direct impacts to mature habitat, especially for old growth and late-successional stands, and wetlands.

- **Mitigation Performance Standard 4.13** – Design alternatives with minimal clearing widths to reduce impacts to existing vegetation.

Mitigation Performance Standard 4.15 – Emphasize planting native, non-palatable, non-attractive vegetation within the right-of-way.

Mitigation Performance Standard 4.16 – Minimize exposed soils and over-steepened slopes during construction.

Mitigation Performance Standard 4.17 – Implement an invasive weed control program with realistic targets/performance standards that comply with land use plans/policies for all revegetation locations. Monitor existing weed conditions to document baseline conditions and to identify new invasives in the future.

Mitigation Performance Standard 4.18 – Coordinate compensatory mitigation efforts with land managers to ensure consistency with any vegetation plans.

Mitigation Performance Standard 4.19 – Where the natural (existing) condition is not desirable, attempt to achieve a desired condition.

Mitigation Performance Standard 4.20 – Identify living and non-living vegetation suitable for salvage prior to clearing/grubbing activities.

Mitigation Performance Standard 4.21 – Retain and use salvaged vegetation for restoration and re-vegetation efforts.

Mitigation Performance Standard 4.22 – Encourage the use of salvaged vegetation for restoration actions instead of new/imported plant material.

Mitigation Performance Standard 4.23 – In restoration/mitigation locations, attempt to mirror a reference location(s) that occurs on either or both sides of the highway.

How do ongoing operational activities relate to protecting ecological connectivity?

The operations to maintain the I-90 corridor need to align with the objectives that have already been noted in other performance standards and BMPs in this section. Maintenance activities should support the connectivity investments that will be made.

Performance Standards

Mitigation Performance Standard 1.4 – Revegetate habitat disturbed during construction activities using native vegetation appropriately to discourage the growth of noxious weeds and to restore natural conditions.

Mitigation Performance Standard 4.8 – Establish special protocols for the application of herbicides, winter traction sand, and de-icer near streams and HCZs.
- **Mitigation Performance Standard 4.9** – Establish a spill response plan for HCZs and wildlife crossings.

- **Mitigation Performance Standard 4.24** – Design alternatives to reduce or eliminate the need for routine ditch and channel maintenance.

- **Mitigation Performance Standard 4.25** – Design structures to minimize routine maintenance. Make them self-maintaining.

- **Mitigation Performance Standard 4.26** – Ensure ongoing monitoring of all compensatory mitigation sites for compliance with performance standards agreed upon as part of the mitigation plan.

- **Mitigation Performance Standard 4.27** – Devise a spill response plan for sensitive areas.

- **Mitigation Performance Standard 4.28** – Minimize/eliminate noxious weeds.

- **Mitigation Performance Standard 4.29** – Manage/control the application of traction sands around terrestrial undercrossings and aquatic passages to maintain native vegetation and water quality.

**Policy Issues and Adjacent Land Uses**

Managing recreation in proximity to CEAs will be vital to increase the effectiveness of wildlife crossing structures. Fortunately, many of the proposed crossing structures are located away from areas of intense human use. However, several prominent structures are planned for areas adjacent to sites that receive moderate or high use during portions of the year. Management of both recreation and development around these sites will be essential so that they are compatible with the goals and objectives of the CEAs. Snowmobiling, off-road driving, and other high-disturbance activities will be managed in a manner that will complement the goals and objectives of the CEAs. There are multiple ownerships and objectives in the I-90 corridor (recreation, transportation, forest, and wildlife management). To ensure the success of this mitigation effort, coordination and cooperative agreements are needed among owners and managers.

Habitat acquisition around the highway corridor is key to ensuring the long-term success of wildlife crossing structures and ecological connectivity throughout the corridor.

The majority of land surrounding I-90 is managed by the U.S. Forest Service. Fortunately, this area is already managed by the Snoqualmie Pass Adaptive Management Area Plan (USDA and USDI 1997) and the Northwest Forest Plan (USDA and USDI 1994), both of which provide a high level of protection and guide management objectives in the area.

**Performance Standards**

For a complete list of performance standards, see Attachment 3.
- **Connectivity Performance Standard 3.3** – Locate wildlife crossing structures in areas where adjacent land ownership and land use is conducive to long-term ecological connectivity.

- **Connectivity Performance Standard 3.4** – Prioritize and allocate resources for wildlife connectivity structures based on consistency with long-term management goals of lands near the approach to wildlife crossing structures and the proper functioning of each structure.

- **Mitigation Performance Standard 3.1** – Develop a cooperative, multi-agency habitat connectivity plan with cooperative agreements for long-term land use management, land acquisition, and road crossings for public and private lands surrounding the project area.

- **Mitigation Performance Standard 3.2** – Develop and implement a cooperative, multi-agency recreation management plan to manage the areas adjacent to CEA crossing structures. This plan will address motorized and non-motorized recreation and the relocation of sno-park and campground facilities.

- **Mitigation Performance Standard 3.14** – Ensure that crossing structure and CEA goals and objectives are consistent with Forest Plan management goals and objectives for timber harvest, roads, and management of recreation.

**Water Quality**

The highway project will add new lanes and other impervious surfaces that could increase pollutant loadings from stormwater runoff. Highway maintenance activities such as herbicide application and winter traction sanding may also affect aquatic resources. These impacts can be minimized using best management practices (BMPs) for stormwater management and maintenance activities. Because there are currently few stormwater BMPs in place on this section of I-90, the project also presents an opportunity to address water quality problems caused by the existing highway. The I-90 project would retrofit the stormwater system to meet current stormwater management requirements, providing water quality and quantity control for paved areas that are now untreated. Performance standards listed on pages 2-15 and 2-16 and in Attachment 3 address water quality issues.

**How do we find the best locations for connectivity structures?**

Assessing the best general locations for wildlife crossing structures in the I-90 corridor focused on three main factors: the types of habitat present in the vicinity, the wildlife activity in the area, and the terrain features that can accommodate crossings. We also

Large overcrossing structure
considered the road geometry and construction feasibility. To maximize benefits of the project, we explored opportunities for combining wildlife crossing structures with planned stream crossings wherever possible.

**Habitat**

Elevation in the project area is highest at Snoqualmie Pass and decreases eastward into the foothills of the Cascade Range. Over the length of the project corridor, elevations decrease from above 3,000 feet to about 2,000 feet above sea level. The climatic conditions, soils, and plant and animal communities change along with the elevation.

Western hemlock associations are the dominant plant associations in the I-90 corridor. Mountain hemlock and Pacific silver fir occur in the western portion of the project area, and grand fir and Douglas-fir associations occur in the eastern portion. The project area can very generally be viewed as containing three zones:

1. From Hyak to the north end of Keechelus Lake (MP 54 to MP 56), subalpine fir and mountain hemlock are the dominant plant series. Here, annual precipitation ranges from 90 to 110 inches.

2. The south end of Keechelus Lake to just beyond the dam (MP 61 to MP 65) is dominated by western hemlock and Pacific silver fir. Here, annual precipitation ranges from 63 to 90 inches.

3. At Amabalis Mountain and Easton Hill (MP 65 to MP 70), grand fir and Douglas-fir constitute the dominant plant series. Here, annual precipitation ranges from 43 to 72 inches (see Exhibit 5-1 in Chapter 5 for a depiction of the zones).

These zones, which are transitional and do not have rigid boundaries, include a variety of important habitat types that differ from the dominant type, such as wetlands and talus slopes. The MDT recognized that these are general classifications that serve as a starting point for assessing the need for wildlife crossing structures, and focused on improving connectivity for species moving within each of the three zones. Further consideration was given to aligning connectivity structures with finer-scale local habitats such as wetlands, riparian areas, and old-growth forest remnants.

**Wildlife Activity**

The MDT evaluated wildlife and habitat information from a number of sources to identify and characterize the use of the project area by various wildlife species. This information included the following:

- Aerial photography

- Wildlife survey data, including habitat inventories, snow tracking, detections from motion-activated cameras, special inventories for “survey and manage” species, wetland studies, and other records of observations
- Relative landscape permeability ratings from Singleton and Lehmkuhl (2000) to identify important focus areas for wildlife movement (Exhibit 2-5)
- Records of animal-vehicle collisions for assessing the presence of deer and elk (Exhibit 2-6)

This information allowed us to identify areas of animal activity. Migratory routes for deer and elk were noted, not only for these species, but as likely corridors for travel by other species. Other records of animals near the road were compared to see if they agree with the noted corridors of movement north and south, and to determine if there were other areas important to wildlife dispersal.

At the local site level, the MDT noted records of species associated with specialized habitats such as talus slopes and forested wetlands. In some cases, these records documented the presence of rare species.

**Terrain**

Our initial focus for connectivity structures was stream crossings under the expanded highway. The stream channels are often constrained at the crossings, many structures are fish passage barriers, and there is little opportunity for terrestrial wildlife passage. WSDOT plans to replace existing structures with larger structures, so the MDT examined these areas to assess how additional expansion or reconfiguration could help improve ecological connectivity.

Some aspects of terrain tend to limit the movement of wildlife. Very steep slopes, rock outcrops, and water bodies may provide habitat for certain species, but generally function to naturally direct wildlife movement around these areas. This led us to de-emphasize connectivity along the northeast shore of Keechelus Lake for example, where steep rocky slopes lead to the lake’s shoreline.

**Connectivity Emphasis Areas**

As a next level of assessment, considering habitat, wildlife activity, and terrain, we identified 15 CEAs. These areas offer the best opportunities for improving ecological connectivity in the project area. These areas were the central focus of the connectivity planning and, in most cases, were considered locations for crossing structures. Each area is evaluated in detail in Chapter 3.

While a substantial level of effort was applied to characterizing the opportunities, evaluating various design alternatives, and developing recommendations for connectivity at each CEA, the MDT recognized that other opportunities to increase the ecological permeability of the road exist outside the CEAs. Small and medium-sized crossings can help with hydrologic connectivity and are known to be used by many small mammals, amphibians, and reptiles. The MDT recommends placement of crossings at intervals of approximately every 820 feet, where constructible and feasible, in both wetland and upland habitat to provide connectivity for these smaller species.

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The 15 CEAs are:
- Coal Creek
- Gold Creek
- Rocky Run Creek
- Wolfe Creek
- Resort Creek
- Townsend Creek
- Price and Noble Creeks
- Bonnie Creek
- Swamp Creek
- Toll Creek
- Cedar Creek
- Telephone Creek
- Hudson Creek
- Easton Hill
- Kachess River
Landscape Permeability for Wildlife Along I-90
Exhibit 2-5
Known Deer and Elk Roadkill Locations in Project Area (1991 to 2001)
Exhibit 2-6
The CEAs are fairly evenly distributed through the corridor. However, ecological connectivity can be further enhanced by keeping culverts as large as possible and providing dry crossings that are distributed throughout the highway corridor, where feasible.

Performance Standards

For a complete list of performance standards, see Attachment 3.

- **Connectivity Performance Standard 3.1** – Site crossings in areas with high landscape permeability; locate crossings that provide connectivity for both high- and low-mobility species within the three “linkage zones” associated with the mountain hemlock/subalpine fir, western hemlock/Pacific silver fir, and grand fir/Douglas-fir plant associations.

- **Connectivity Performance Standard 3.2** – Design connectivity structures to conform to topography.

- **Connectivity Performance Standard 3.3** – Locate wildlife crossing structures in areas where the adjacent land ownership and land use is conducive to long-term ecological connectivity.

- **Connectivity Performance Standard 3.5** – Provide a minimum of one large overpass or terrestrial underpass for each mile of constructed roadway.

- **Connectivity Performance Standard 3.6** – Provide additional crossing structures (e.g., full culvert, open-bottom culvert, concrete box culvert) at intervals of approximately 820 feet of highway, where constructible and feasible, to accommodate small- and medium-sized animals with small home ranges.

**What are the attributes of effective crossing structures?**

Thus far, we have addressed connectivity objectives and recommended means for achieving these objectives at the landscape and corridor-wide scales. In this section, we narrow our focus to the scale of individual CEAs.

The first step in determining the locations and attributes of effective crossing structures is an understanding of the dynamic nature of the particular ecosystems represented. A crossing structure design and location that is suitable for current ecological conditions may be inadequate to meet ecological connectivity needs near the end of the structure’s life. This aspect of crossing structure design and location is often overlooked. Crossing structures are static and have service life spans of 70 to 80 years. Natural landscapes and ecological communities are dynamic, and can change substantially during this time interval due to species redistribution and recolonization, plant succession, altered habitat conditions, and management efforts (e.g., species recovery plans). While developing connectivity objectives and performance standards, we kept the future in mind and attempted to anticipate the changes in ecological conditions that are likely to occur in the project area over the next 50 to 100 years.
With the dynamic nature of the ecosystems in mind, and to increase the likelihood that crossing structures proposed in each CEA would effectively link populations of organisms across the highway corridor, we developed a set of recommendations about how to design and locate these structures. These recommendations fell into four interrelated groups:

- **Group 1: Design for ecological integrity**
- **Group 2: Design for openness**
- **Group 3: Location**
- **Group 4: Integration with fencing**

In the following sections, we present our rationale for these recommendations as well as key underlying assumptions. We made simplifying assumptions when existing information about crossing structures was insufficient or equivocal. Our rationale is primarily based on studies of the effectiveness of existing crossing structures from around North America, and on basic ecological principles.

**Group 1: Design for Ecological Integrity**

In the next four sections, performance standards precede our summaries of pertinent scientific literature that provide the rationale for adopting specific standards. We used this approach to discuss crossing structure attributes because of the large number of relevant performance standards and the large volumes of scientific information pertinent to particular standards.

- **Connectivity Performance Standard 3.11** – Accommodate both high- and low-mobility species dispersal in high priority CEAs (Gold, Price/Noble, Bonnie, Swamp, Toll, Hudson, Easton, and Kachess).

- **Connectivity Performance Standard 3.14** – Design wildlife crossing structures to minimize the intensity of noise and light emanating from the highway.

- **Connectivity Performance Standard 3.16** – Design crossing structures to allow for future species redistribution and recolonization due to improved habitat conditions, recovery plans, or re-introductions (e.g. grizzly bear, wolf, lynx, fisher).

Most studies of crossing structure effectiveness have focused on high-mobility, large mammal species (e.g., Clevenger and Waltho 2005). For these species, both basic dispersal biology and particular behavioral preferences relative to crossing...
structure design and location have been studied, allowing a higher level of refinement in our recommendations. These more-specific recommendations are presented below in sections dealing with individual features that have been associated with crossing structure effectiveness for large mammals.

Design recommendations for low-mobility species are more challenging. Low-mobility species are those that would need from several days to several generations to pass through crossing structures in a highway corridor (Beier and Loe 1992). For effective linkage of these species, all of the habitat components needed to complete their life cycle have to be present within the crossing structure (Beier and Loe 1992). The dispersal biology, behavioral preferences, and physiological tolerances of many low-mobility species are not well understood. This contributes to uncertainty about how to design crossing structures that provide effective linkages among populations of these species.

The MDT’s approach to dealing with this uncertainty was to focus on ecological integrity within crossing structures as a surrogate for detailed information about the biological requirements of the wide variety of low-mobility species found near the highway corridor (Hunter 1999). Ecological integrity refers to the completeness of a biological system, including the presence of all the elements at appropriate densities and the occurrence of all the processes at appropriate rates (Angermeier and Karr 1994).

Using ecological integrity as a surrogate required the MDT to make two broad assumptions about how this surrogate relates to our objective of effective passage of low-mobility species:

- Ecological integrity is in the eye and the response of the beholder (Begon et al. 1990). How the different low-mobility “beholders” that are present in the corridor perceive their world and move through it is largely unknown. We used our professional judgment about patterns of habitat selection in low-mobility species to emphasize a subset of habitat factors and processes that, if present within crossing structures, were likely to improve effectiveness. The MDT’s premise was that microhabitat complexity within crossing structures was the key attribute, and that vegetative development was the process that contributed most to this attribute. In other words, we assumed that if vegetative complexity and species in the crossing were similar to what was present in undisturbed forests near the highway, then the crossing would provide the microhabitat needed for the passage of most low-mobility animal species. Because plant distribution is governed by a well known set of factors (soils, moisture, temperature, and light), meeting the crossing structure performance goal would involve making these factors within the structures similar to those in surrounding forests. Beyond vegetative development, additional habitat features that may be important to some low-mobility species may need to be added (e.g., large woody debris, talus). Adverse factors that could form barriers to movement, such as accumulations of contaminants, would also need to be avoided or minimized near crossing structures. In this regard, use of
stormwater BMPs to minimize contaminants in both terrestrial and aquatic habitats may enhance crossing structure effectiveness (Forman et al. 2003).

- Linking habitats in each of the three distinct vegetative assemblages along the highway corridor would provide effective linkages between populations of the majority of low-mobility species occupying these habitats.

Support for these assumptions comes mainly from studies that have demonstrated that species such as small mammals (Goosem 2001, Clark et al. 2001), arthropods (Mader et al. 1990), mollusks (Baur and Baur 1989), and lizards (Tiebout and Anderson 1996) will avoid dispersing through unsuitable habitat. In the project area, species with limited dispersal capabilities and narrow ecological tolerances include land snails, slugs, and Plethodontid salamander species, all of which are likely to benefit from maintaining ecosystem integrity within crossing structures. These species may take several days to several seasons to disperse through a crossing structure. For example, one study of a terrestrial snail found that the mean distance moved after three months, approximately one season of activity, was only 5 to 16 feet (Baur and Baur 1989).

For both high- and low-mobility species, artificial light and excessive noise, including traffic noise, are potentially important types of human disturbance (Beier and Loe 1992). Artificial light can attract or repulse animals, and these responses can affect foraging, reproduction, and communication. For example, dispersing mountain lions avoid lighted areas to such a degree that artificial lighting has been proposed as a deterrent to keep animals from entering habitat areas surrounded by human housing (Beier 1995). Changes in the behavior and ecology of single species can in turn disrupt interspecific interactions, with potentially serious implications for community ecology (Longcore and Rich 2004). Relatively little is known about the ecological consequences of artificial lighting, but a few well-documented examples suggest the effects can be severe, and that ecologists have not adequately considered these effects on the ecological function of reserves and corridors (Longcore and Rich 2004). Crossing structures are a type of corridor that, due to their narrowness and association with vehicle headlights, are particularly susceptible to negative lighting effects that reduce effectiveness in linking populations.

Road noise also alters the behavior of animals, especially in habitat use, and can contribute to a road-avoidance zone (Forman and Alexander 1998). It can also harm the health of animals, interfere with reproduction, and reduce survival (Forman et al. 2003, Bowles 1995). Reducing noise levels in the vicinity of
crossing structures may increase structure effectiveness by reducing avoidance responses. Placing roadways in tunnels provides the best wildlife crossings because habitat is left intact and disturbances from traffic noise and light are nearly eliminated. Viaducts designed to minimize noise are the most effective undercrossings (Forman et al. 2003). Noise can be reduced by laying down a quieter road surface and by using structural solutions or soil berms and natural features to decrease noise propagation (Forman et al. 2003).

Vibration induced by noise or passing traffic can have adverse effects on plants and animal species that use vibrations to detect prey or avoid predation, especially reptiles (Forman et al. 2003, Rudolph et al. 1999). We are not aware of any studies that document the attenuation of vibration in undercrossings, but presumably, surrounding piers of multi-span bridges and bridge abutments with vibration-absorbing materials could attenuate vibration more rapidly and reduce the area of the crossing structure that is affected.

Artificial lighting and irrigation beneath wildlife underpasses may have a role in aiding the growth of vegetation and promoting microhabitat complexity within wildlife underpasses. Highways with three lanes of traffic in each direction and shoulders, such as the proposed configuration for I-90, can be over 120 feet in width if lanes are bundled together without a median. Natural lighting sufficient to support plant growth is unlikely to reach fully under such a broad structure unless clearance beneath the structure is very high. For low-clearance underpasses, supplemental artificial lighting, timed to match the natural photoperiod, may enhance crossing structure effectiveness for low-mobility species, while not compromising use by high-mobility species that tend to avoid artificial lighting. The location of the proposed project on slopes with predominant southerly aspects will improve the amount of natural light reaching under structures. Many plants in the forests of the project area are highly shade tolerant, which also increases the potential for successful plant growth within connectivity structures.

- **Connectivity Performance Standard 1.3** – Design wildlife crossing structures to accommodate aquatic, riparian, and terrestrial habitat components.

- **Mitigation Performance Standard 3.16** – Maximize habitat cover in the vicinity of crossing structures’ entrances.

Distance to cover is a variable that has been identified repeatedly as an important determinant of passage functionality for high-mobility species (e.g., Clevenger and Waltho 2005). Some authors have identified amount of vegetative cover at passage entrances as an essential design component (Hunt et al. 1987; Rodriguez et al. 1996), and vegetation removal along roadways has been suggested as a means for reducing the attractiveness of roadsides to deer and other herbivores (Putman 1997). However, the association between distance to cover and passage effectiveness can be positive for some species (ungulates and grizzly bears) and negative for others (mountain lions) (Clevenger and Waltho 2005). As is the case...
for structure openness, which is described below, different species appear to have different preferences, suggesting that multiple approaches to vegetation management within and among crossing structures may yield the best performance.

Limited information is available about how the width of a linear gap in vegetation affects the permeability of that gap to animal movements. However, the movements of forest birds, among the most mobile of wildlife species, are influenced by gaps in forest cover as small as 162 feet (Desrochers and Hannon 1997). The assumption that permeability is likely inversely proportional to the width of the gap seems reasonable for most species (Trombulak and Frissell 2000). Thus, for the majority of smaller mammals and low-mobility species, having cover in close proximity to the crossing structure is likely to improve performance.

- **Connectivity Performance Standard 3.13**  – Maximize continuity of native soils adjacent to and within bridges and on wildlife overpass structures.

Maintaining native soil continuity in crossing structures may enhance connections among populations of plants, animals, and fungi. Maintaining plant diversity and native soils is critical to maintaining ecological integrity (Zak et al. 2003). High productivity in the forests surrounding the project area is the result of a favorable and complex interaction of climate, geology, vegetation, and soils (Heilman et al. 1981). The structure and nutrient content of soils influence not only the type of vegetation that can develop on a site, but also the animals that are present (Hanson and Rotella 1999). The potential influence of soils on fungal diversity is unknown, largely because little is known about the ecological factors that affect the distribution of fungi (Amaranthus 1999). However, the diversity of fungi in Pacific Northwest forests is among the highest ever encountered (Amaranthus 1999). This diversity may reflect fungal specialization along environmental gradients, symbiotic associations with plants that have specific habitat requirements, or a combination of these and other factors. Field surveys have suggested that some fungi in the project area may be associated with particular soil types (Garvey-Darda 2002).

Non-native plants are common along roads (Forman et al. 2003). In some cases, imported roadbed materials have been implicated as contributing to the development and spread of non-native species (e.g., Greenberg et al. 1997).
Using native soils in crossing structures may make it easier to transplant native species, thereby discouraging colonization and spread of non-native plants. Native soils in crossing structures may benefit animals directly and indirectly. Direct benefits would occur primarily for soil invertebrates and burrowing vertebrates.

- **Mitigation Performance Standard 3.8** – Maximize microhabitat complexity within crossing structures using salvage materials (e.g., logs, root wads, rocks) to encourage use by arboreal species, species associated with downed logs, and species associated with rocky substrates.

Large woody debris is a type of salvage material that can contribute substantially to increasing microhabitat complexity within crossing structures (Krajick 2001). Large woody debris plays a major role in the suitability of habitat for terrestrial and aquatic species (Laudenslayer et al. 2002). For example, in Oregon and Washington forests, 74 wildlife species are associated with downed coarse (large) woody debris (Marcot 2002). Coarse woody debris is also important for a wide variety of invertebrates, many of which feed on fungi in downed logs, and are preyed upon by insectivores (Koenigs et al. 2002). Decay of woody debris creates a moisture-retentive microhabitat that influences plant colonization and growth (Lee and Sturgess 2002) and contributes to soil nutrients and texture (Prescott and Laiho 2002).

Placing large woody debris in crossing structures is likely to increase their effectiveness for low-mobility species, especially species that need large wood and moist microhabitats to complete their life cycles (e.g., mollusks and amphibians). Wood structures may also be placed within crossing structures to encourage use by semi-arboreal species such as flying squirrels. The Okanogan and Wenatchee National Forests have standards for stocking levels of large woody debris in different habitats (see Wenatchee National Forest 1997). The DecAID model provides guidance about the size, amount, and distribution of dead and decaying wood necessary to maintain wildlife habitat and ecosystem functions (http://www.fs.fed.us/wildecology/decaid/decaid_background/decaid_home.htm). Achieving or exceeding these stocking levels within passage structures is a readily measured performance standard.

The diversity and abundance of soil macroinvertebrates are lower near roads, which may be due to reduced organic litter depth along roadways (Haskell 2000). Enhancing organic litter depth near and within crossing structures may be another strategy for increasing successful crossings by macroinvertebrates. Like large wood, organic litter could be collected from areas affected by new lane construction, stockpiled, and distributed to crossing structures. The percentage of the crossing structure surface covered to a specified depth with organic litter is another easily monitored performance measure.
Group 2: Design for Openness

- **Connectivity Performance Standard 3.7** – Where feasible, reduce the length of crossing structures by bundling lanes (keeping them together rather than separated by a central median).

- **Connectivity Performance Standard 3.8** – Maximize openness of structures (high, wide, and short from entrance to exit) by providing a minimum clearance of at least 16 feet (to provide 12 feet of clearance over the typical 4-foot snow depth). A clearance of up to 20 to 30 feet under structures may be desirable to allow native vegetation to become established. This will facilitate plant-to-plant contact and native conditions, which would increase the structure’s effectiveness for low-mobility species.

- **Connectivity Performance Standard 3.9** – Provide effective wildlife passage year round by using designs that accommodate snow depths (including snow plow berms typical of the project area; maintain a minimum of at least 16 feet (to provide 12 feet of clearance over the typical 4-foot snow depth).

- **Mitigation Performance Standard 3.17** – Encourage development of native vegetation within the crossing structures by using designs that provide natural lighting whenever possible, and artificial lighting when needed.

Scientists debate about the relative importance of different factors affecting wildlife use of crossing structures. Location and structure design are the two factors most often associated with crossing structure performance. Location sub-factors that have been identified as important contributors to effectiveness include position of the crossing relative to landscape features, surrounding habitat quality, and habitat disturbance (Yanes et al. 1995; Clevenger and Waltho 2000). Other studies have shown that the design of structures can be most important (Norman et al. 1998; N. Waltho pers. comm. 2002). The “location vs. design” debate likely reflects real differences among wildlife species in their preferences for different types of structures. Discordant results may also be the result of the use of different methods, such as analyses being conducted at different spatial or temporal scales, and by failure to account for confounding variables. Reliable information about structure effectiveness is sparse because few highway crossing structures have been monitored using a rigorous pre- and post-construction sampling design, and because monitoring has not continued long enough to allow for wildlife to habituate to new structures (see Forman 2003, p. 156-161, for further discussion).

Based on available information, we believe that both location and design are important determinants of crossing structure effectiveness. Support for this position comes primarily from the best-
investigated set of crossing structures in Banff National Park (Exhibit 2-7). Two analyses of effectiveness of these structures have been conducted. The first analysis of older structures found location and landscape context had the biggest influence on the performance of crossing structures (Clevenger and Waltho 2000). The second analysis, which includes newer crossing structures with less human disturbance, revealed that, for carnivores, both location and structural factors were equally important in explaining passage, but for ungulates, structural attributes were most important (N. Waltho pers. comm. 2002, Forman et al. 2003).

For structural attributes, crossing structures with high openness ratios attracted grizzly bears, wolves, elk, and deer, while more constricted crossing structures were preferred by black bears and mountain lions (N. Waltho pers. comm. 2002).

Information about the effectiveness of crossing structures in other locations tends to be focused on a narrower range of species, or is not analyzed in a comparable fashion. These studies, nonetheless, provide insights into attributes of crossing structures preferred by some species in some locations. In contrast to the Banff results, long and low undercrossings that are similar in size to those in Banff have been found to inhibit use by carnivores, including mountain lions, in some locations (Beier and Loe 1992, Foster and Humphrey 1995). Ungulates have been more widely studied than other species, resulting in recommendations that underpasses be at least 23 feet wide and 8 feet high and have vegetation nearby (reviewed in Forman et al. 2003). Ungulates may favor more open structures, in part, because some evidence suggests that predators may use highway crossing structures to capture prey (Foster and Humphrey 1995). Restrictive or narrow
structures may reduce the ability of prey species to avoid detection or to escape if chased (Yanes et al. 1995). A review of existing literature about the potential for mammalian predators to exploit wildlife crossing structures as prey-traps (locations where prey species are funneled in high concentrations) provided scant evidence to support this concept (Little et al. 2002). Instead, the limited incidents of predation documented during crossing structure studies suggest infrequent opportunistic events, rather than recurring predation, and predators appear to use different crossing structures than their prey (Little et al. 2002).

To the best of our knowledge, existing width and height recommendations for ungulates do not include consideration of any highways that are six lanes wide or that are in areas with persistent deep snow. The MDT’s minimum height recommendation of at least 16 feet (to provide 12 feet of clearance over the typical 4-foot snow depth) is intended to compensate for the greater width of the I-90 project, which can diminish the perceived openness of a structure (Jacobson 2002), and to provide clearance in the presence of typical snow accumulations and deeper roadside snow berms.

For most of February and March, the average daily snow depth at Snoqualmie Pass stays above 7 feet, with depths averaging above 4 feet for the same period at the dam at Keechelus Lake (Western Region Climate Center 2005). Snow depths from Hyak to the top of Easton Hill, as measured by WSDOT in February 2004, were consistently close to 4 feet (C. Wilbour pers. comm. 2004). During this same period, the average daily snow depth at Kachess Lake was 2.5 feet for most
of February and March, peaking at about 3 feet in late February. Maximum snow depths occurred in 1946, ranging from 12 feet at Keechelus Lake to 9 feet at Kachess Lake. Based on these overall measurements, 6 feet represents a reasonable average snow depth for wildlife crossing structures at Gold Creek, which is close to Snoqualmie Pass, and 4 feet represents an appropriate average snow depth for structures from Price and Noble Creeks to Easton Hill (Exhibit 2-8).

![Average Snow Depth at Snoqualmie Pass, Lake Keechelus, and Easton Hill Over a 50-Year Period](source: Western Regional Climate Center (2005)).

For many species, especially rare ones, not enough data about crossing preferences are available to analyze structure attributes that influence performance. One potential approach to this problem is to group species into guilds (e.g., carnivores, ungulates), and evaluate structure performance for the entire guild (N. Waltho pers. comm. 2002). The risk associated with this approach is that the needs of rare species that are habitat specialists or that have particular behavioral tendencies will not be met.

Increasing the openness of structures improves the potential for developing natural vegetation within structures. This in turn improves the chances for developing microclimatic conditions conducive to the survival, reproduction, and dispersal of low-mobility species. Throughout the MDT process, minimum vertical clearances for wildlife undercrossings have been discussed as a critical attribute to encourage wildlife use. It is also important that the conditions in and around the crossings blend with natural conditions. The MDT recognized that due to irregularity in the existing ground surface there may be some slight variation in the exact clearance achieved. See Attachment 5 for the openness ratios calculated for each of the CEAs.

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1 It is the MDT’s expectation that, where minimum clearances are addressed in design development, this clearance will be achieved as a minimum throughout all or nearly all of that structure with the possible exception of small natural topographic features. Some areas may exceed this clearance, which is an added benefit for connectivity. In cases where the stated vertical clearance cannot be achieved, the structure should be further evaluated to ensure that adequate passability is provided.
Examples of Small, Medium, and Large Crossing Structures

As mentioned previously, to be most effective, structures should be located in areas of high landscape permeability, meaning areas where terrain and habitat converge. In addition, the crossing structures themselves will be more effective for some species if they contain habitat, rather than simply being physical connections between habitat on opposite sides of the highway. For instance, lower mobility animals will feel relatively more secure crossing a structure if it contains hiding cover. Following is a description of small, medium, and large structures and what animals would be expected to use them. Attachment 5 provides information about the sizes and types of structures proposed for this project, along with their corresponding openness ratios.

Small Structures
These structures are small-diameter, round culverts and small box culverts that are typically installed for drainage under highways and measure 5 feet or less at their widest dimension. A variety of small mammals, amphibians, and reptiles are known to use small structures to cross under highways.

The recommended approach on this project is to install small (or medium) structures, as dry culverts where possible, at intervals of approximately every 820 feet of highway, where constructible and feasible, in areas between the larger structures to provide connectivity for these smaller species.

Medium Structures
These are large box culverts or small bridges, with their widest dimension over 5 feet, but having a wildlife passage with less than 12 feet vertical clearance or less than 100 feet width inside.

Medium structures would be used by many of the same animals that use small structures, although some species may prefer the protection that the smaller structures provide. Medium structures also can accommodate some bigger animals. Black bears and mountain lions will use crossing structures in this size range. Observations at crossings in Banff National Park, Alberta, Canada, indicate that mountain lions appear to prefer crossing structures with greater cover and lower openness ratios. Deer will also use these, although they tend to use larger structures more readily.

Medium structures, especially those toward the larger end of this size category, can include some habitat elements such as root wads or other structures that provide cover and microhabitat for smaller animals.

Large Structures
Large structures include wildlife overcrossings (with unlimited openness) and bridge spans that provide a wildlife passage that is at least 12 feet high over typical snow depth and 100 feet wide. Vertical clearance of at least 12 feet is required in areas with heavy snow accumulations to allow winter use. Large structures provide the greatest degree of openness and allow for passage by the
largest animals and those that are not inclined to enter more constricted structures. Because these are used by many of the species that also use small and medium structures, the large structures allow for passage by the broadest range of animals.

Far-ranging animals such as deer, elk, and grizzly bear prefer the large crossing structures. These structures also provide an opportunity to create a wider corridor that accommodates more habitat types (such as stream, wetland, and upland) and would be more attractive to a wider variety of species. Large structures also can contain more habitat elements within the crossing structure itself (such as root wads, logs, and vegetation), which are expected to encourage use by low-mobility species.

Large structures, especially under-crossing structures, are also more effective than others for supporting the connectivity of ecological processes, especially stream processes such as channel migration, uninterrupted surface water and groundwater movement, and woody debris transport.

Group 3: Location (see also pages 2-30 to 2-35)

- **Connectivity Performance Standard 3.1** – Site crossings in areas with high landscape permeability; locate crossings that provide connectivity for both high- and low-mobility species within the three “linkage zones” associated with the mountain hemlock/subalpine fir, western hemlock/Pacific silver fir, and grand fir/Douglas-fir plant associations.

- **Connectivity Performance Standard 3.2** – Design connectivity structures to conform to topography.

The objectives of the MDT regarding ecological connectivity encompass both physical and biological processes of the ecosystems adjacent to I-90. For example, we considered hydrologic continuity of wetlands to be as important as movement of individuals or propagules. We sought to develop a system of crossing structures that would provide process continuity and population viability, not just for indicator habitats or species, but for the entire natural community present in the I-90 corridor. This broad objective is relevant to the issue of locating crossing structures in that we could not simply focus on habitat suitability for a few key species as the primary guide for locating structures. Instead, we focused on key physical processes and the distribution of natural communities as defined by vegetative associations.

The MDT developed a map-and-matrix-based approach to compile information and to determine where biological values overlapped in the project area in order to locate areas where crossing structures would provide multiple benefits. The conceptual model underlying this approach assumes that ecological processes and ecological community structure in the project corridor are largely determined by precipitation, hydrology, and edaphic factors. Physical factors were considered to be drivers of ecological patterns and processes. Thus, physical processes provide the initial coarse-scale insights regarding effective placement.
of passage features to maintain ecological connectivity. Beyond the apparent ecological merits of this approach to locating crossing structures, focusing on hydrologic processes and soil types also offered the opportunity to meet many regulatory mitigation needs.

The MDT applied two additional guidelines to the question of where to locate passage features. First, we assumed that low-mobility species are most sensitive to the location and microhabitat conditions in crossing structures. Preliminary surveys of the distribution of low-mobility “Survey and Manage” species in the vicinity suggested that soil type may provide a useful cue to the distribution of these species (Garvey Darda 2002). Thus, linking areas of similar soil types that are separated by the highway corridor may be an appropriate guideline to use to locate crossing structures. This approach was used only for soil types that had a relatively contiguous distribution in the valley bottom before highway construction (attempting to link patches of soil types that are naturally separate in their distribution does not serve connectivity needs).

The second guideline was to determine the degree to which passage features located based on physical factors would meet the needs of high-mobility species at risk in the project area. We reviewed the autecology of these species to identify particular species with unmet connectivity needs that may require passage features in locations that match their specialized habitat preferences. Previous studies have identified habitat suitability as the primary indicator of crossing activity (e.g., Barnum 2003). For example, lynx use of highway underpasses has been documented in Banff National Park (Heuer 1995, cited in Ruediger et al. 2000). However, compared to gray wolves and grizzly bears, lynx are more specialized in their habitat selection.

Although lynx use a wide variety of habitats during long-distance dispersal movements, suitable habitat for foraging and denning is generally considered to consist of forest types that include subalpine fir (Abies lasiocarpa), Englemann spruce (Picea engelmannii), lodgepole pine (Pinus contorta), and quaking aspen (Populus tremuloides) (Koehler 1990). Lynx appear to prefer to travel through continuous forest, using the highest terrain available such as ridges or saddles, although they also use riparian areas (Koehler 1990). Lynx also appear to prefer areas with low topographic relief and less steep slopes (Koehler and Aubry 1994; Apps 2000). Thus, passage features that will accommodate lynx movements should be located in as close proximity as possible to suitable habitat types and near gentle ridges with relatively contiguous cover. Mapping of key linkage areas where highway-crossing structures may provide connectivity benefits and reduce mortality is called for in the Lynx Conservation Strategy and Assessment (Ruediger et al. 2000). These maps have been developed for the project area (Singleton and Lehmkuhl 2000, Singleton et al. 2002). The parts of the project area that most

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**Autocology** refers to the ecology of individual organisms or species.
closely correspond to these criteria are near Coal and Gold Creeks, near Amabalis Mountain, and near Easton Hill (see Singleton and Lehmkuhl 2000).

- **Connectivity Performance Standard 3.3** – Locate wildlife crossing structures in areas where the adjacent land ownership and land use is conducive to long-term ecological connectivity.

- **Connectivity Performance Standard 3.5** – Provide a minimum of one large overpass or terrestrial underpass for each mile of constructed roadway.

- **Connectivity Performance Standard 3.6** – Provide additional crossing structures (e.g., full culvert, open-bottom culvert, concrete box culvert) at intervals of approximately 820 feet of highway, where constructible and feasible, to accommodate small and medium-sized animals with small home ranges.

Crossing structures are needed at sufficient intervals to allow for the movement of large animals and animals with large home ranges, as well as for organisms that are less mobile, have more specialized habitat needs (e.g., talus or old growth forest associated species), or found in localized populations and sporadic dispersal events (e.g., mountain goats, marmots, pikas). Researchers in Banff National Park recommend culverts every 820 feet (Clevenger et al. 2001b, Clevenger et al. 2002).

### Group 4: Integration with Fencing

- **Mitigation Performance Standard 2.4** – Use legacy structures (e.g., large logs, root wads), vegetation and other habitat features, and fencing to facilitate wildlife use of large crossing structures.

We discussed the critical role of fencing and other forms of wildlife exclusion in the performance of crossing structures earlier in this chapter (pages 2-22 to 2-26). At this point in project planning, an integrated plan to encourage wildlife use of crossing structures and exclude wildlife from the highway surface has not been developed. We consider such a plan essential to meet connectivity objectives. We also recognize that developing this plan will be challenging. Private land ownership, recreational interests, visual issues, potential for unintended biological consequences, integration with drainage and stormwater management, and installation and maintenance difficulties, among other factors, will all need to be considered in the development of this integrated plan. The complexity of these challenges suggests that detailed planning for wildlife exclusion should begin as soon as possible.

### How can we tell if the connectivity structures are working?

Monitoring is an important part of assessing the effectiveness of the connectivity improvements. Monitoring must be conducted both to characterize baseline conditions and to assess wildlife use and hydrologic connectivity improvements after the project has been completed.
Baseline studies would build on existing data from I-90 project-related studies as well as USFS data. For example, winter snow tracking, motion-activated camera surveys, track pits, and smoke plates have been used in the project area to characterize wildlife use. Other methods that have been employed along highways in Washington include hair snag surveys and tracking radio-collared animals (e.g., WDFW mountain lion radiotelemetry study, Koehler 2006).

We recommend wildlife studies involving all the linkage zones in the project area, with a focus in the identified CEAs. We recommend hydrologic connectivity studies throughout the project corridor, with an emphasis on CEAs and HCZs.

Once improvements are in place, performance monitoring should be implemented at new connectivity structures. Research has shown that some species may use structures right away, but several years may be needed for most species to discover and habituate to the new structure. Because the project is likely to be implemented in phases over the course of many years, early monitoring results may be useful in refining the design and implementation of later phases.

Performance Standards

- **Mitigation Performance Standard 5.1** – Establish and implement monitoring plans at each CEA to determine whether established performance standards for the project area are being met. When one or more performance standards for an individual CEA drop below average performance standards established for the project area, adaptive management procedures are triggered that determine the cause and develop and implement corrective actions.

- **Mitigation Performance Standard 5.2** – Develop and implement a monitoring plan to address wildlife exclusion methods. This plan will include systematic data collection of observations of animals that have either climbed over or gotten though the fence, fence ends, other potential openings, gaps, or deficiencies.

- **Mitigation Performance Standard 5.3** – Develop and implement a monitoring plan to evaluate the effectiveness of wildlife crossing structures.

- **Mitigation Performance Standard 5.4** – Develop and implement a monitoring plan to ensure that water quality is maintained and improved.

- **Mitigation Performance Standard 5.5** – Conduct ongoing monitoring of hydrologic and other physical attributes of aquatic, riparian, and wetland habitat within CEAs and near HCZs.
CHAPTER 3

Connectivity Emphasis Areas
Chapter Three  Connectivity Emphasis Areas

Introduction

This is the most important chapter of this recommendation package because it presents our comparative evaluation of design options at each CEA. Our evaluation is based on CEA-specific objectives we developed from studies of the project area, and a set of performance standards that we derived from the concepts summarized in Chapter 2. We translated these performance standards into evaluation questions, which we used to address each CEA design option. This chapter begins with a detailed description of this evaluation approach, including a listing of our evaluation questions. The remainder of the chapter is a series of sections that deal with individual CEAs. The CEAs are discussed in order from the western project boundary to the eastern project boundary.

Each CEA section is in turn composed of a series of subsections:

- A description of existing conditions
- A list of our CEA-specific objectives
- A physical description of the design options proposed for the CEA
- A comparative evaluation of how the options are likely to perform
- Recommended restoration measures
- Identification of other potential restoration opportunities.

Each section is followed by a comprehensive comparison table that presents the “nuts and bolts” of our evaluation of the design alternatives or options for that CEA. We cannot overemphasize the importance of these tables. They are broken down into two main categories—wildlife connectivity and hydrologic connectivity. Each of these categories is further broken down into series of evaluation questions that we derived from the performance standards presented in Chapter 2 and compiled in Attachment 3. Each question evaluates all of the design alternatives or options for that CEA; our rationale for whether an alternative or option would meet a performance standard is presented in the “Comments” column. Our evaluation of the likely performance of the alternatives and options also considers the objectives for that CEA.

We summarize the results of our evaluation process in the sections entitled How will the options perform? These sections review CEA-specific objectives for wildlife and hydrology, describe additional information needs, and present our comparative assessment of the likely performance of each option. We conclude these summaries of our findings with a list of “recommended restoration measures.” Aggregation of these CEA-specific findings into a corridor-wide finding is the topic of Chapter 4.

Our distinction between “recommended restoration measures” and “other potential restoration opportunities” deserves further explanation. Discipline reports and sufficiency reports written in support of the project identified a
number of opportunities to improve ecological connectivity in the project area. We reviewed these reports, compiled a list of these opportunities, and identified additional opportunities based on the historic and current conditions at each CEA and our objectives for that CEA. Measures that we consider essential to the effective performance of crossing structures are included in our lists of “recommended restoration measures.” Under the heading *Are there other potential enhancement opportunities?*, we list opportunities that are typically off-site or out-of-kind mitigation opportunities. We do not consider implementation of these actions to be essential to the proper functioning of crossing structures. These opportunities may go beyond the scope of the proposed project, or may be beyond the authority of FHWA and WSDOT to complete. We identified these additional restoration opportunities to encourage cooperating agencies and private entities to implement projects that we believe will contribute to improving ecological connectivity from Hyak to Easton.

How did we evaluate design options at CEAs?

The IDT charged the MDT with several tasks to be completed in the process of analyzing the sufficiency of different design options for CEAs. These tasks included both comparing existing connectivity conditions to conditions that would result from building different options and evaluating how well different options satisfied connectivity objectives. Performance standards and best management practices (BMPs) were important tools in our completion of these tasks, but the way we used these tools differed between our April 2004 draft recommendation package and the current version.

In our April 2004 draft recommendation package, we described and evaluated the conditions in each CEA based on criteria relating to the functionality of existing habitat types (see Attachment 1). Our approach was first to describe conditions of existing habitat given the current I-90 facility and to compare that baseline to alternative scenarios in which different design options were constructed at each CEA. This evaluation approach facilitated comparing existing conditions to anticipated future conditions under different proposed options.

This approach, however, also had the undesirable effect of reducing the transparency of our evaluations about how well the options would satisfy the connectivity objectives. In particular, our evaluation approach based on habitat function was not explicitly linked to our performance standards for crossing structures. These performance standards present our most detailed articulation of the measures that would contribute to meeting connectivity objectives. We used these standards implicitly to guide our assessment of the likelihood that different design options would improve habitat function and thereby fulfill ecological connectivity objectives. However, in our April 2004 draft recommendation package, we expressed both our evaluations and our conclusions in terms of habitat function, rather than in terms of performance standards.

Not surprisingly, readers of the 2004 recommendation package had questions about the relationship between the MDT’s performance standards for the project.
and habitat function. In particular, the IDT sought clarification about the degree to which different design options satisfied performance standards. For the IDT, this information was considered to be important for differentiating among design options while in the process of recommending a preferred alternative for the project.

To clarify how different design options satisfy connectivity objectives, in this revised recommendation package we changed our assessment process to focus on performance standards. For each CEA, we address a series of questions derived directly from the performance standards. As a team, we qualitatively integrated our responses to these questions to reach our joint conclusions about the likelihood of different design options meeting connectivity objectives.

We based our evaluations on WSDOT design information current at the time of publication. Although future designs are likely to change to some degree, original design information is available in the MDT final design file records.

We evaluated design options that were more conceptual than finished (i.e., about 30 percent complete). Consequently, many questions remain at most CEAs regarding constructability to meet performance standards and ability to integrate different project components (e.g., integrating crossing structures, wildlife exclusion, HCZs, and stormwater treatment). Recognizing these uncertainties, we generally assumed “best-case-scenarios” in which conceptual designs would be implemented to maximize adherence to performance standards and minimize trade-offs that might compromise ecological connectivity. We anticipate that ongoing coordination between the design team and the MDT will be necessary to refine integrated designs and optimize connectivity performance.

The alternatives and design options for realigning portions of the road at CEAs could result in the abandonment of portions of the existing I-90 road prism. We assumed that the disposal of pavement and roadfill material from abandoned portions of the highway would either be reincorporated into the roadbed or disposed of in areas that do not compromise the function of CEAs or HCZs.

We did not evaluate the effects of the Keechelus Lake Alignment Alternatives on ecological connectivity. These alignment alternatives, however, influenced our CEA-specific objectives and our evaluation of options designed for CEAs along Keechelus Lake. We discuss this issue in our evaluations of the Rocky Run, Wolfe Creek, and Resort Creek CEAs.

How well do the connectivity options meet the ecological connectivity objectives?

We evaluated each design option based on (a) its ability to meet the unique ecological objectives established for each CEA or HCZ, and (b) key questions developed to reflect our goals and objectives and connectivity performance standards. Questions used to evaluate the performance of each design option are presented below. Goals and objectives and associated connectivity performance
standards identified in Chapter 2 are embedded in each question and are noted in parentheses. The answers to these questions are provided in the comparison tables provided at the end of each CEA section in Chapter 3.

**Wildlife and Habitat Connectivity Questions at the CEA/HCZ Scale**

- Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)? (Goals and Objectives #1, #2, and #3)

- Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light? (Goals and Objectives #3)

- Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present? (Goals and Objectives #3)

- Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)? (Goals and Objectives #3)

- Are populations of species associated with different habitat types in this CEA connected? (Goals and Objectives #1, #2, and #3)

- Can human activities in this CEA be managed for compatibility with the function of the crossing structures? (Goals and Objectives #3)

- Is the adjacent land owned by public parties? (Goals and Objectives #3)

**Hydrologic Connectivity Questions at the CEA/HCZ Scale**

- Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats? (Objectives #1 and #4)

- Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans? (Objective #4)

- Does this option avoid impacts on wetland hydroperiods? (Objectives #1 and #4)

- Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands? (Objectives #1 and #4)

- Does this option restore natural surface and subsurface flow paths through the I-90 roadbed? (Objectives #1 and #4)
Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, floodprone areas, and shallow groundwater and emergence zones? (Objectives #1 and #4)

Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas? (Objectives #1 and #4)
3.1 Coal Creek CEA

What are the conditions at Coal Creek?

The Coal Creek CEA (Exhibit 3.1-1) is located between MP 55.1 and MP 55.2. Its drainage area is 3,616 acres. Coal Creek flows under I-90 through two long culverts and under a series of bridges before it empties into the head of Keechelus Lake.

Vegetation Community

The important habitats in the Coal Creek CEA include Coal Creek, wetlands at Mardee Lake, and riparian and forest habitats. The forest in the area is Pacific Silver Fir and Mountain Hemlock forest series (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The Pacific Silver Fir associations typically occur at lower elevations and the Mountain Hemlock Series at higher elevations within the Coal Creek CEA. The tree species within these series include mountain hemlock, subalpine fir, Pacific silver fir, western hemlock, Douglas-fir, western white pine, western redcedar, western larch, grand fir, and lodgepole pine. Coal Creek and Gold Creek are the only CEAs that contain the Mountain Hemlock Series. Red osier dogwood and coyote willow are the dominant vegetation in riparian and wetland areas. The Coal Creek CEA contains a unique assemblage of plant and animal species associated with mountain hemlock and subalpine fir.

Wildlife/Terrestrial Species Linkages

The Coal Creek CEA provides the opportunity to link forest, riparian, and stream habitat and the species associated with these habitats on both sides of I-90. This CEA has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, shrews, voles, snakes, salamanders, and mollusks, as well as many rare species such as wolverine, lynx, and gray wolf. Coal Creek and Gold Creek present the only opportunity to provide linkage for a group of species.
or subspecies unique to the western portion of the project area, such as marten, pika (*Ochotona princeps brunnescens*), golden-mantled ground squirrel, yellow pine chipmunk (*Tamias amoenus ludibundus*), and a host of lichen, bryophyte, fungi, and vascular plant species associated with old growth mountain hemlock and subalpine fir (Garvey-Darda and Worthington 2003). The Coal Creek CEA also provides a critical linkage of riparian habitats between Mardee Lake and wetlands associated with Keechelus Lake.

The Coal Creek and Gold Creek CEAs are critical areas for linking the Alpine Lakes Wilderness to the Norse Peak Wilderness, which in turn links to other wilderness areas and national parks throughout the Washington Cascades (see Exhibit 1-2).

Bear and coyote were documented adjacent to I-90 during surveys by Singleton and Lehmkuhl (2000). American marten and bushy-tailed woodrat were also photographed using the large box culverts on Coal Creek under I-90.

Mardee Lake is a high quality bog-like wetland maintained by a beaver dam situated in a tributary of Coal Creek. The lake supports large populations of Western toads and other pond amphibians. Upstream of Mardee Lake and I-90, two beaver ponds near the project area support amphibians and provide habitat for pond-breeding amphibians (although breeding habitat is limited). Tailed frogs have been seen in the tributaries of some of these wetlands areas. Pacific giant salamanders have been seen in Coal Creek below I-90.

Overland dispersal of amphibians such as western toads in the Coal Creek area is limited to the north side of I-90, but there is good connectivity between the Coal Creek wetlands upstream of I-90 and Mardee Lake (WSDOT 2002b).

The soil in the Coal Creek area consists of K187 Chikamin Sandy Loam at 5 to 30 percent slopes. There are several rare and/or commercially important fungi species associated with this soil, including *Boletus mirabilis, Gomphus clavatus, Gomphus kauffmanii, Gyromitra californica, Hericium abietis, Mycena overholtsii* (USFS 1994; Garvey-Darda and Worthington 2003).

The road density in the Coal Creek subwatershed is 6.9 miles of road per square mile.¹ The U.S. Forest Service has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape habitat conditions in the future.

East of Coal Creek, there is private development associated with the community of Hyak. Coal Creek runs through the WSDOT maintenance facility for 0.5 mile. High quality habitat is located within 1 mile to the north and south of I-90.

The MDT characterized terrestrial habitat and linkages in Coal Creek as not properly functioning because of public and private land uses near I-90, reservoir

¹ Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated the road.
fluctuation, and the I-90 roadway itself, which blocks terrestrial species movement.

**Stream Channel Function**

Coal Creek is a moderate-gradient stream. The stream channel has been moved from its original location many times over the last several decades. Streamflow changes have influenced both the peak flows and the low flows due to the highway and adjacent road network that confined Coal Creek to an artificially narrow floodplain. The stream channel is disconnected from its floodplain. The last downstream crossing of Coal Creek is a bridge that spans the active channel. The creek below this point flows past the Hyak maintenance facility in an entrenched channel before entering a deep rock-walled canyon. This naturally confined channel has virtually no floodplain, and the streambed is made up of large cobbles and boulders.

**Wetlands**

Historically, wetlands occurred throughout the Coal Creek riparian area in the portion of Keechelus Lake that is seasonally inundated today. Today, the upper reach of Coal Creek contains high quality wetlands and beaver habitat.

**Water Quality**

The MDT cited water quality in Coal Creek as not properly functioning. Specific contributing factors include temperature (lack of riparian vegetation/shade), sediment (traction sand from both I-90 and an adjacent WSDOT maintenance facility), and the presence of metals (lead and arsenic) in stormwater runoff.

**Fish Species and Aquatic Habitat Linkages**

During aquatic surveys (WSDOT 2002b), cutthroat trout, mountain whitefish, and sculpins were found upstream and downstream of I-90. Several species, such as burbot and redside shiner, were only found downstream of I-90.

Upstream of I-90, aquatic habitat in Coal Creek is not properly functioning due to substrate embeddedness and low-flow problems. The upstream I-90 culverts (outside of the project limits) are barriers to fish passage. The I-90 bridge crossing (which is within the project limits) is not a fish passage barrier under most flow conditions.

Outside the project area, Coal Creek flows under I-90 through two long box culverts that are barriers to fish passage at all flows. Within the project area, Coal Creek passes under a series of four adjacent bridges: one on Forest Service Road 4832, two on I-90 (spans of 56 feet westbound and 50 feet eastbound, both with vertical abutments), and a wooden bridge on the frontage road leading to the Hyak maintenance facility. The I-90 eastbound bridge is not a barrier, but it constrains the channel and may form a partial velocity barrier at high flows (WSDOT 2002, p. 28).
What are the objectives at Coal Creek?

- Provide a moderate level of connectivity for small mammals and amphibians.
- Provide passage for fish and other aquatic organisms moving through the stream.
- Improve water quality in Coal Creek to address problems associated with high water temperatures, fine sediment, and heavy metals.

What design options did we evaluate at Coal Creek?

Coal Creek is within the project limits; however, design options were not prepared because the highway is already six lanes at this location and is not scheduled for replacement. We consider this CEA to have limited wildlife and hydrologic connectivity opportunities. See the following sections for our assessment of the Coal Creek CEA.

How will the project affect Coal Creek?

The existing bridges over Coal Creek that are within the project limits meet our modest objectives for wildlife connectivity at this CEA. Exhibit 3.1-2 is an aerial view that shows the proposed changes in the vicinity of Coal Creek. These bridges offer limited crossing opportunities for terrestrial wildlife and amphibians at lower stream flows. Better opportunities for improving wildlife connectivity are outside the project limits, just to the west at the corner of section 10 and 16 (T. 22 N., R. 11 E.W.M.), nearer the Cascade crest, and at Gold Creek.
Opportunities at Coal Creek for floodplain and stream channel restoration are limited in the project area because the stream channel downstream of I-90 is confined within a narrow rock-walled canyon. The existing bridge structure provides adequate fish passage. Our hydrologic connectivity objectives therefore focus on water quality problems associated with high water temperatures, fine sediment, and heavy metals. The I-90 project will address these issues by upgrading the highway's stormwater management system to the current standards in WSDOT's *Highway Runoff Manual* (WSDOT 2004).

**Performance Standards**

Site-specific performance standards that apply to this CEA will be determined at a later date (see Attachment 3).

**Are there other potential enhancement opportunities?**

The proposed project does not include replacement of any culverts or bridges associated with Coal Creek. We suggest the following measures to increase ecological connectivity at this location. These measures would not involve major reconstruction of the highway.

- Provide opportunities for small mammals and amphibians to cross under the highway by installing small dry culverts through existing fill near existing crossings.

- Attempt to enhance or supplement the existing long culverts that are fish passage barriers in ways that will permit fish passage during some flow conditions.

- Restore the stream channel adjacent to the WSDOT Hyak maintenance facility, including establishing a riparian buffer and limiting runoff of traction sand and pollutants.

- Improve shading by planting native trees and shrubs along the streambank. Provide filtration of pollutants from runoff to improve water quality.

- Reduce riparian impacts from Washington State Parks’ Iron Horse Trailhead.

- Reduce impacts from the WSDOT Hyak maintenance facility. Past efforts to reduce inputs of traction sand into Coal Creek from the storage area at the maintenance facility have been partially successful. Moving the traction sand stockpile farther back from Coal Creek to develop a broader riparian strip would provide a means for trapping excess sediment before it reaches the creek. Relocating the stockpile to an alternative location without creek frontage would be most effective (WSDOT 2002b).

- Restore a potential unconfined aquifer identified by the MDT in the area of MP 54.5, which exists at a depth of 80 to 150 feet beneath the ground surface. This is based on information contained in the *Geology and Soils Discipline Report* (HartCrowser 2002) and field observations. This aquifer was
intercepted during previous highway construction projects, resulting in accelerated discharge of groundwater. Restoration could include establishing infiltration areas to allow water to be absorbed and stored beneath the ground to augment stream discharge. These infiltration areas should not receive untreated runoff from roads and other pollutant sources to minimize contamination of shallow aquifers.
3.2 Gold Creek (Valley) CEA

What are the conditions at Gold Creek?

The Gold Creek CEA (Exhibit 3.2-1) is located between MP 55.2 and MP 55.8. Gold Creek empties into the northwest tip of Keechelus Lake just downstream of I-90. I-90 spans Gold Creek with a 138-foot (westbound) and 126-foot bridge (eastbound). Forest Service Road 4832 spans Gold Creek upstream of I-90 with a 110-foot bridge. Exhibit 3.2-2 shows an aerial view of the Gold Creek CEA.

Vegetation Community

The important habitats in the Gold Creek CEA include Gold Creek, wetlands at Mardee Lake and associated with Gold Creek, and riparian and mature/old growth forest. The forest is Pacific Silver Fir and Mountain Hemlock forest series (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The Pacific Silver Fir associations typically occur at lower elevations and the Mountain Hemlock Series at higher elevations within the Gold Creek CEA. The tree species within these series include mountain hemlock, subalpine fir, Pacific silver fir, western hemlock, Douglas-fir, western white pine, western redcedar, western larch, grand fir, and lodgepole pine.

North of I-90, Gold Creek is a broad floodplain with thickets of alder, willow, and red-osier dogwood, with mature/old growth forest on the slopes above Gold Creek. South of I-90, Gold Creek flows
Mountain goats into Keechelus Lake. The shoreline includes wetlands and mid-seral forest on the slopes to the west. Coal Creek and Gold Creek are the only CEAs with Mountain Hemlock Series present. The Gold Creek CEA provides the opportunity to link forest, riparian, stream, and wetland habitat and the species associated with these habitats on both sides of I-90.

Vegetation communities found within the Gold Creek CEA include the mountain hemlock-subalpine fir forests and associated plant communities. This area was logged approximately 70 to 80 years ago, and, therefore, little herbaceous vegetation occurs within the understory of its closed canopy. Steep side slopes rise from Gold Creek’s valley floor. Thickets of alder, willow, and red-osier dogwood provide additional habitat along the valley floor of Gold Creek. Mature forests occur upstream of the I-90 corridor, where the headwaters of Gold Creek originate in the Alpine Lakes Wilderness Area.

The Gold Creek CEA has been cited as a critical link in both north-south and east-west movement of wildlife associated with late successional forests such as mountain goat and wolverine (see Exhibit 1-2) (USFS 1999).

**Wildlife/Terrestrial Species Linkages**

The Gold Creek CEA provides the best opportunity to link wilderness areas to the north and south of I-90. Wilderness areas are particularly important habitat for rare wide-ranging species that are sensitive to roads, such as wolverine, lynx,
grizzly bear, and gray wolf. This CEA also provides the best opportunity to provide linkage for a group of species or subspecies unique to the western portion of the project area, such as pika (*Ochotona prince brunnescens*), golden-mantled ground squirrel, yellow pine chipmunk (*Tamias amoenus ludibundus*), and a host of unique lichen, bryophyte, fungi, and vascular plant species associated with old growth mountain hemlock and subalpine fir found at Snoqualmie Pass. This CEA can also provide linkage for a large assemblage of more common high- and low-mobility species, including deer, elk, black bear, mountain lion, coyote, fox, shrews, voles, snakes, salamanders, frogs, and mollusks.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks expected to be present in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2. Garvey-Darda and Worthington (2003) list the rare bryophyte and lichen species found during surveys in the project area.

In surveys conducted by Singleton and Lehmkuhl (2000), American marten were detected only at Gold Creek during all seasons; automatic camera surveys indicated that elk, mule deer, black bear, bobcat, coyote, spotted skunk, Douglas squirrel, Northern flying squirrel, and snowshoe hare are common in the Gold Creek valley. Singleton and Lehmkuhl (2000) also documented that Gold Creek is one of the highest roadkill locations for deer and elk in the project area, with collisions occurring in spring, summer, and fall.

Mardee Lake, which is next to Gold Creek, is an important breeding habitat for amphibians, including Northwestern salamander, rough-skinned newt, western toad, Cascade frog, Pacific tree frog, and long-toed salamander (WSDOT 2002b). These species are at risk on roadways during the breeding season, when they migrate into ponds and when they leave ponds after metamorphosis. *Ensatina eschscholtzii*, a strictly terrestrial salamander (no aquatic life history phase), has also been documented in the old growth forest habitat adjacent to I-90 and Gold Creek (Garvey-Darda pers. comm. 2005).

Mollusk species that occur in the Gold Creek area are *Ancotrema sportella*, *Haplotrema vancouverversense*, *Prophysaon vannattae*, and *Vertigo columbiana*. Another mollusk species (*Pristiloma awascoense*) appears to occur only in the Snoqualmie Pass area.

The dominant soils in the Gold Creek drainage area, and the rare and/or commercially important fungi species associated with these soils, are as follows (USFS 1994; USFS 2003):
- K189 Chickamin-Rock outcrop complex, 30 to 70 percent slopes, which supports *Boletus mirabilis*, *Cantharellus subalbidus*, *Hygrophorus bakerensis*, and *Rhizopogon evadens*. This soil type occurs in the forested habitat on the west side of Gold Creek next to I-90.

- K323 Cryorthents, 0 to 3 percent slopes, which supports *Boletus mirabilis*, *Dentinum repandum*, *Gomphus clavatus*, and *Laetioporus sulphureus*. This soil type occurs within the Gold Creek drainage area.

Habitat linkages in the Gold Creek area can be negatively affected when the Keechelus Lake reservoir is at full pool (elevation 2,517 feet) (Exhibit 3.2-3). For an average 2 to 3 months a year, the area under the bridge is completely inundated, creating a barrier for terrestrial species attempting to move through the area.

The road density in the Gold Creek subwatershed is 0.42 mile of road per square mile. The low road density generally indicates good habitat for large, wide-ranging carnivore species (Thiel 1985).

The public uses the Gold Creek area to access the Alpine Lakes Wilderness and Gold Creek Pond. In addition, the Gold Creek bridge and Forest Service Road 4832 are used as a Sno-park for motorized and nonmotorized winter sports. Appropriate management of recreation in the area will be important to maintaining habitat effectiveness for wildlife.

The Mill Creek section to the south of Gold Creek was recently added to the National Forest system; however, additional public lands are needed to increase the effectiveness of this area to provide connected habitats.
Stream Channel Function

Gold Creek drains 8,937 acres and is the largest Yakima River tributary upstream of the Kachess River.

The Gold Creek valley was carved by glaciers and meltwater from a series of alpine glaciations, ending with the Lakedale drift 15,000 years ago (Hart Crowser 2002). Meltwater from these glaciers carried coarse debris down the stream valleys and into the Upper Yakima River basin. Meltwater sediments eventually built up the terminal moraines that formed Keechelus Lake, Kachess Lake, and Lake Cle Elum. After the most recent glaciation, Gold Creek reworked the glacial sediments and created its modern floodplain. The floodplain was bounded by rock outcrops and terraces of glacial outwash sediment left behind by meltwater. Gold Creek meandered freely across a forested floodplain before entering Keechelus Lake.

Constructing the Keechelus Lake dam raised the lake level by 97 feet; Keechelus Lake provides flood control and irrigation in the Yakima River system (Hart Crowser 2002). The dam enlarged the natural lake and inundated the lower reaches of Gold Creek. Gold Creek formed a new sediment delta at the upstream end of the enlarged lake, just below the existing I-90 crossing.

The USBR operates the Keechelus Lake dam to store water during the winter and spring for summer release to irrigators in the Yakima River Basin. The normal high pool elevation is at 2,517 feet mean sea level, which inundates the Gold Creek delta up to the Forest Service Road 4832 bridge. By the end of the irrigation season in late summer, the reservoir is typically drawn down below 2,470 feet mean sea level, exposing much of the Gold Creek delta below I-90. During winter flood events, the reservoir level may temporarily rise above 2,500 feet, but in most years the delta remains exposed until the reservoir fills with snowmelt between March and June (see Exhibit 3.2-3).

Construction of I-90 and Forest Service Road 4832 further altered the hydrology and geomorphic structure of Gold Creek. These roads were constructed on fill across most of the historical floodplain, and bridges confined Gold Creek to a single active channel. Borrow pits and staging areas were constructed on the floodplain along both sides of the highway. A large borrow pit upstream of Forest Service Road 4832 confined Gold Creek to the western margin of its historical

Downstream of I-90 looking toward Keechelus Lake

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floodplain, leaving behind a pond that is fed by seepage and discharges through an artificial outlet channel to Gold Creek. Reaches of Gold Creek upstream of the pond outlet often dewater by mid-summer.

Gold Creek’s channel function is poor. The creek has a limited capacity for bedload transport and channel migration is constrained. The floodplain is artificially constrained, which contributes to channel aggradation through constriction scour and the resulting sediment deposition downstream. The I-90 and Forest Service Road 4832 bridges artificially confine the Gold Creek channel, limiting channel migration and the development of natural floodplain features. The potential channel migration zone if the road beds were removed would be 660 feet wide at the Forest Service Road 4832 bridge, and 1,300 to 1,400 feet wide at the eastbound I-90 bridge. Reservoir inundation alters natural channel processes below Forest Service Road 4832 for several months each year, but from late summer through early winter, the delta is exposed and channels are shaped primarily by streamflows from upstream.

Wetlands

The Gold Creek valley and Keechelus Lake shoreline contain wetland habitat alongside the existing highway structure that provides abundant forage and habitat opportunities for wildlife. All wetlands in this area are rated Category II using the Eastern Washington Wetland Rating System (Hruby 2004). The wetland system associated with Keechelus Lake is a complex mixture of palustrine open water, emergent and scrub-shrub wetlands; wetlands associated with Gold Creek include riverine scrub-shrub.
Functions provided by the wetlands associated with Keechelus Lake include general habitat suitability, especially for invertebrates, amphibians, and wetland-associated birds, plus erosion control around Gold Creek and the potential for removing toxicants.

Functions at wetland areas associated with Gold Creek are limited to flood flow alteration; sediment, nutrient and toxics removal; and shoreline stabilization. The effects of reservoir operations after the Keechelus Dam is repaired may reduce the effectiveness of this system. The Gold Creek wetlands are currently somewhat disconnected from the Gold Creek floodplain because of the existing I-90 highway and the Forest Service road and bridge directly upstream. Deposition has occurred between the roadways and large sandbars may prevent some surface flow into these wetland areas.

**Water Quality**

Gold Creek is one of two streams in the project area on the Washington State 303(d) list for temperature exceedance (the other is the Yakima River from Keechelus Dam to the Easton Reservoir). The high temperatures in Gold Creek are due to sediment deposition, streambed aggradation, and the lack of riparian vegetation and shade structures.

**Fish Species and Aquatic Habitat Linkages**

Among the streams that flow into Keechelus Lake, Gold Creek is the only documented bull trout spawning stream. Bull trout are listed as threatened under the Endangered Species Act, and the population in the Keechelus subbasin is at high risk due to low numbers of spawning adults (about 100 to 200 adults), isolation above an impassible dam, and use of only one spawning stream that often dewatered in mid-summer below their spawning area. Bull trout spend most of the year in Keechelus Lake and migrate in summer and fall to spawn in the upper reaches of Gold Creek. Seasonal dewatering occurs between the outlet of Gold Creek Pond (about 3,300 feet north of I-90) and a point about 2 miles upstream, blocking access to the spawning area and trapping some adult bull trout in the project area below the dewatered reach. Due to this dewatering, bull trout and kokanee redds have been observed between the bridges on I-90 and Forest Service Road 4832. Many factors contribute to the dewatering. The dewatered zone defines a break between the relatively pristine upper portion of the watershed and the more modified lower channel.
In addition to bull trout, many other fish species occur in Gold Creek, including kokanee, cutthroat, rainbow, and brook trout; burbot; sculpins; redside shiners; mountain whitefish; and mountain suckers (WSDOT 2002b).

Gold Creek is not a properly functioning stream, which compromises its aquatic habitat and linkages, channel function, floodplains, water quality, and terrestrial linkages. Gold Creek’s seasonal dewatering negatively affects aquatic linkages, and the habitat complexity for aquatic and riparian species has been greatly diminished. In addition, Gold Creek is inundated by the Keechelus Lake reservoir during the summer season, which further complicates its connectivity solutions because lake levels extend upstream beyond Forest Service Road 4832 during this period.

**What are the objectives at Gold Creek?**

- Provide a high level of year-around connectivity for high- and low-mobility species associated with the mountain hemlock-subalpine fir forests, riparian habitats, wetlands, and floodplains. Year-round connectivity will require high structures (minimum 18 feet) due to winter snowpack. Bridges 20+ feet high would provide light under the structures to support plant life and increase the openness of the structure.

- Provide a high level of connectivity across the reservoir bed during the period of the year when the reservoir is drawn down.

- Build structures that would provide connectivity for wildlife species associated with the mountain hemlock-subalpine fir habitat type. These species include at least 46 species of mammals, 12 species of amphibians, and 13 species of mollusks documented or suspected to occur in the area (see Attachment 2).

- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.

- Restore channel migration processes and reduce floodplain confinement, to the extent practical given constraints posed by reservoir inundation and upstream channel changes, particularly upstream of I-90 where floodplains and associated wetlands are not inundated by Keechelus Lake.

- Restore capacity to convey flood flows, sediment, and debris through the Gold Creek crossing structure.

- Provide fish passage at the highway crossing for the full range of lake elevations.

- Improve water quality by properly treating stormwater and highway runoff, and minimizing de-icer chemical use.
What design options did we evaluate at Gold Creek?

Four options are under consideration at Gold Creek (Exhibit 3.2-4). The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment.

**Option A**

Option A would construct twin bridges along the western edge of the historic Gold Creek floodplain. These bridges would have an approximate vertical clearance ranging from 20 to 22 feet and a length of approximately 120 feet.

Twin multi-span bridges (approximately 1,100 feet eastbound and 900 feet westbound) would be constructed across Gold Creek’s active channel migration zone. These bridges would have an approximate vertical clearance ranging from 16 to 25 feet.

Raising the roadway profile to provide sufficient vertical clearance for the bridges at the western edge of the floodplain would require a temporary detour across Gold Creek, which would increase the construction time by at least one season.

**Option B**

Option B would construct twin multi-span bridges (approximately 1,200 feet eastbound and 1,000 feet westbound) across most of Gold Creek’s active channel migration zone. A 100-foot-wide wildlife crossing (connectivity bench) would be constructed adjacent to the west abutment of the bridge. The vertical clearance would be approximately 18 feet above the bench and range from 15 to 26 feet above the lake bed.

Raising the roadway profile to provide vertical clearance at the connectivity bench would require a temporary detour across Gold Creek, which would increase the construction time by at least one season.

**Option C**

Option C would construct twin bridges along the western edge of the historic Gold Creek floodplain. These bridges would have an approximate vertical clearance ranging from 9 to 12 feet and a length of approximately 120 feet.

Twin multi-span bridges (approximately 300 feet long, with an approximate vertical clearance ranging from 15 to 23 feet) would be constructed across Gold Creek.
Gold Creek CEA, Option A
Exhibit 3.2-4a

Gold Creek CEA, Option B
Exhibit 3.2-4b
Gold Creek CEA, Option C
Exhibit 3.2-4c

Gold Creek CEA, Option D
Exhibit 3.2-4d
The lower profile on the western bridges (12 feet, compared to the 20-foot approximate clearance provided by Options A, B, and D) would eliminate the need for a temporary detour bridge across Gold Creek.

**Option D**

Option D would construct twin bridges along the western edge of the historic Gold Creek floodplain. These bridges would have an approximate vertical clearance ranging from 20 to 22 feet and a length of approximately 120 feet.

Twin multi-span bridges (approximately 700 feet long, with an approximate vertical clearance ranging from 19 to 25 feet) would be constructed across Gold Creek.

Raising the roadway profile to provide sufficient vertical clearance for the bridges at the western edge of the floodplain would require a temporary detour across Gold Creek, which would increase the construction time by at least one season.

**How will the options perform?**

The MDT’s objectives for wildlife connectivity at the Gold Creek CEA focus on providing year-round linkage for species found in the mountain hemlock/subalpine fir plant association. We expect high-mobility species such as gray wolf, lynx, wolverine, bobcat, coyote, deer, mountain goat, and elk, as well as many riparian-associated species such as mink and weasel to use the upland habitats adjacent to Gold Creek and the west end of Keechelus Lake. Because this is the only large crossing in this linkage zone, terrestrial connectivity is needed year-round, both in winter when snowpack is high and during the spring and early to mid summer when lake levels are high. Due to constraints on crossing-structure location, we did not set the objective in this CEA of providing connectivity for certain low-mobility species, such as mollusks associated with specific soils or moist forest conditions.

The Gold Creek crossing is located in a complex sediment deposition zone governed by the combined influences of streamflows and reservoir inundation. Hydrologic objectives for this CEA emphasized restoration of natural channel processes and improvement of fish passage and water quality.

A detailed geomorphic study of channel migration and sediment transport processes is needed to

![View of existing westbound I-90 bridge, looking upstream toward the Forest Service Road 4832 bridge](image)
determine if it is desirable and feasible to engineer a dynamically stable channel beneath the Gold Creek bridges that would improve flow conditions for fish passage.

Options A and B

We find that the design of Options A and B would meet overall wildlife connectivity objectives at this CEA. Both options have the size and clearance attributes needed to provide for year-round connectivity of terrestrial species and adequately link habitats in the CEA. Human activity in the vicinity is a concern, including private ownership of nearby parcels, but levels of human use are not currently incompatible with crossing structure performance.

These options meet hydrologic connectivity objectives, and provide equivalent hydrologic benefits. Both options include bridges that span the majority of the active floodplain and channel migration zone. This would improve hydrologic connectivity and habitat functions within an extensive complex of floodplain wetlands, stream channels, and remnant channel features. The eastern end of the bridges should be located to connect with remnant channel features on the east side of the Gold Creek floodplain.

Option C

Option C would not meet wildlife connectivity objectives, unless the wildlife bridge on the western edge of the floodplain could be modified to be about 18 feet high to allow for average snow depths of 6 feet. This would help maintain the minimum 12-foot clearance necessary, even when deep snowpack is present. Retaining walls inside this crossing structure would increase structure openness and likely increase its effectiveness.

This option does not meet hydrologic connectivity objectives because it does not provide sufficient floodplain width to allow natural channel migration upstream of the highway. Option C provides only 300 feet of floodplain width, out of a total of about 700 feet that is needed for proper floodplain function.

Option D

Lengthening the Gold Creek bridge in Option C to about 700 feet and increasing clearance to 18 feet under the wildlife undercrossing to the west would meet wildlife connectivity needs. When snow is deep, lake levels are typically low, exposing extensive portions of the upper lakebed in this area. It is likely that animals would also travel out into the dry lakebed and cross under the Gold Creek bridge.
This option meets hydrologic connectivity objectives by providing sufficient floodplain width to allow natural channel migration upstream of the highway where the floodplain is not routinely inundated by the Keechelus Lake. Options A and B provide greater potential for channel migration, but most of this would occur in areas where lake inundation limits natural channel processes.

See Exhibit 3.2-5 for a detailed comparison of the options for this CEA.

**Recommended Restoration Measures**

- Remove or replace the Gold Creek bridge on Forest Service Road 4832. The ecological benefits associated with the I-90 Gold Creek crossing structures would not be fully realized unless this bridge is removed or replaced to allow channel migration and terrestrial species movement.

- Add large woody debris to Gold Creek to improve habitat complexity. Designs for woody debris placement should consider the effects of reservoir inundation on woody debris transport, and potential impacts of woody debris on bridge piers.

- Adhere to seasonal work windows to minimize potential adverse effects on bull trout from demolition and construction activities.

**Performance Standards**

All performance standards apply to the Gold Creek CEA, except Mitigation Performance Standard 3.5 (performance standards are listed in Attachment 3).

**Are there other potential restoration opportunities at Gold Creek?**

- Acquire private land near the proposed crossing structure (e.g., Miller Shingle property adjacent to I-90). Work with USBR to develop a reservoir storage mitigation plan that would reduce the maximum pool elevation of Keechelus Lake (WSDOT 2002b). Components that could be used in this plan include purchase or lease of water rights/contracts, water-use efficiency improvements, and water banking, as well as direct replacement of capacity by excavation within Keechelus Lake or at another Yakima River Basin reservoir. Manage acquired parcels to maintain or improve habitat integrity, and promote wildlife access to the Gold Creek crossing structure.

- Restore riparian vegetation on Gold Creek both upstream and downstream of I-90. Work with USBR to develop a reservoir storage mitigation plan that will reduce the maximum pool elevation of Keechelus Lake (WSDOT 2002b). Components that could be used in this plan include purchase or lease of water rights/contracts, water-use efficiency improvements, and water banking, as well as direct replacement of capacity by excavation within Keechelus Lake or at another Yakima River Basin reservoir. Current reservoir operations allow only shrubby vegetation that is tolerant of inundation to develop along Gold
Creek (e.g., willow species). At the highest normal reservoir storage level (2,517 feet mean sea level [MSL]), the Gold Creek channel is inundated to a point upstream of Forest Service Road 4832. However, the wetted width of Gold Creek is greater than the shade cast by shrubby vegetation. Direct sunlight reaching the stream channel increases water temperatures, reducing habitat suitability for species that prefer cold water, such as bull trout. If the maximum pool elevation of Keechelus Lake were reduced to about 2,500 feet, trees could be more easily established downstream of I-90. Shade from these trees would moderate stream temperatures, and large woody debris inputs would provide nutrients, cover, and habitat complexity. Development of trees downstream of I-90 would also benefit year-round terrestrial connectivity at this location.

- Conduct a hydrologic study of groundwater and surface water interaction to determine factors contributing to the dewatering of the Gold Creek channel upstream of I-90 (WSDOT 2002b). Include in the scope of work an evaluation of the relative effectiveness of specific restoration options such as:
  - Filling to natural grade and sealing all or a part of Gold Creek Pond.
  - Removing the western berm of Gold Creek Pond, which may be constraining the natural meander pattern of Gold Creek (Pierce 2005).
  - Developing wetlands near or in the old borrow pit.
  - Revise the pond outlet elevation to improve interactions between the creek, groundwater, and the pond.

- Reduce impacts from the WSDOT Hyak maintenance facility.
  - Relocate the maintenance facility away from Gold Creek; this would be the most effective means for avoiding impacts on CEA effectiveness.
  - If relocation is not an option, minimize disturbance effects of the facility. Wildlife using the Gold Creek crossing structures may be disturbed by human activities at the maintenance facility, including above-ambient noise and artificial light. Building an earthen berm on the Gold Creek side of the facility and encouraging development of mature vegetation on this berm could shield the Gold Creek CEA from both noise and light. Disturbance to the Gold Creek CEA could also be minimized by adding baffles to outdoor lights, and adjusting parking and traffic flow patterns within the facility to reduce artificial light directed toward Gold Creek.

- Investigate the feasibility of constructing a crossing structure that links subalpine fir-mountain hemlock habitat in the Hyak vicinity. The proposed structures at Gold Creek only marginally connect this habitat type. Alternative locations for structures outside the boundaries of the current project could be evaluated as a separate project.
## Gold Creek Options Comparison Table

### Exhibit 3.2-5

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>Wildlife crossing structure would be closer to linkage area identified in Singleton and Lehmkuhl (2000).</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Mountain hemlock-subalpine fir zone would not be as well connected as other options because of lack of west-end wildlife bridge.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Attributes of Crossing Structure</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td>This is an open area where it would be difficult to shield wildlife. Fill and plant vegetation would be needed for screening. There is a potential here to buffer wildlife from the WSDOT Hyak maintenance facility.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>Yes</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</th>
<th>B</th>
<th>Yes</th>
</tr>
</thead>
</table>

| C | No | The 12-foot clearance may not provide effective passage when snow is deep; therefore, this option may not meet year-round passage goal. This option provides very limited opportunity for wildlife movement at the only crossing in this particular ecological zone of the project (mountain hemlock-subalpine fir zone). |
| D | Yes |

| Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)? | A | Yes | Yes, for soils that are typical of floodplains. The alluvium in this CEA may not match the native soil type of adjacent uplands. This is the best opportunity in the project area to connect low-mobility species associated with mountain hemlock-subalpine fir species, but it does not connect habitats. |
|---------------------------------------------------------------------------------------------------------------|---|-----|

| B | Yes | Yes, but less than in Option A because of greater distance to structure for forest-associated low-mobility species. This option would provide a better opportunity for vegetation development on bench because of the lane separation. |
| C | No | Low-mobility species would have limited opportunity to cross here successfully. |
| D | Yes | Same as Option A. |
## Gold Creek Options Comparison Table

**Exhibit 3.2-5**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>Yes</td>
<td>This option would provide good connections for multiple habitat types.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option’s forest habitat would not be as well connected.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>The reduced clearance height of this option may reduce potential for within-structure habitat development.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A, except that narrower width of bridge might reduce connection opportunities or multiple habitat types.</td>
</tr>
</tbody>
</table>

Can human activities in this CEA be managed for compatibility with the function of the crossing structures?  

<table>
<thead>
<tr>
<th></th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>Yes</td>
<td>The west side of this CEA has a lower level of human use and the WSDOT Hyak maintenance facility is also present. There is a moderate level of seasonal use (not currently a high level of incompatible human activity in CEA vicinity). An increase in activity could reach a level of incompatible effects. The east side of the Gold Creek valley connects well to wilderness, except for one private parcel, Sno-park, and access road to Gold Creek pond. The west side also provides connection currently, but more private ownership.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>

Is the adjacent land owned by public parties?  

<table>
<thead>
<tr>
<th></th>
<th>Option</th>
<th>Mostly</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>Mostly</td>
<td>This CEA contains a few private parcels in important locations.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Mostly</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Mostly</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Mostly</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>

### Hydrologic Connectivity

<table>
<thead>
<tr>
<th></th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>A</td>
<td>Yes</td>
<td>This option would restore natural sediment transport, maintain aquatic habitat linkage, and increase habitat complexity. There would be some low to moderate stream temperature reductions because of less aggradation.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Shorter span would limit riparian functions and passage of wood, debris, and sediment by confining overbank flood flows.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>

Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?  

<table>
<thead>
<tr>
<th></th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>Yes</td>
<td>This option would accommodate full channel migration upstream of the highway and a substantial portion of the channel migration zone downstream. Location of the spans would need to be adjusted to match historical channel features.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>No, for 300-foot bridge.</td>
</tr>
</tbody>
</table>
### Gold Creek Options Comparison Table

#### Exhibit 3.2-5

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>D</td>
<td>Yes</td>
<td>This option would accommodate full channel migration upstream of the highway where floodplains and associated wetlands are not inundated by Keechelus Lake.</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Yes</td>
<td>This option would improve hydrologic function, but character of the wetlands would change over time in response to floodplain processes and channel migration. This would restore a more dynamic and diverse wetland ecosystem.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Similar to Option A, but to a lesser extent because of the narrower restoration area.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>Yes</td>
<td>This option would restore flow paths between upslope wetlands and downslope delta environment.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option would block wetland flow through 60 percent of the potential floodplain restoration area.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>This option would block wetland flow through 30 percent of the potential floodplain restoration area.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>This option would restore groundwater and surface water flows under 1,000 feet of highway.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option would restore groundwater and surface water flows under 1,000 feet of highway and flow paths between upslope wetlands and downslope delta environment.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option would restore flow paths under only 300 feet of highway, blocking wetland flow across most of the potential Gold Creek floodplain width.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>This option would restore groundwater and surface water flows under 700 feet of highway.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove fill from 1,000 feet of prehighway floodplain.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>This option would remove fill from 300 feet of prehighway floodplain.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>This option would remove fill from 700 feet of prehighway floodplain.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove fill from 1,000 feet of prehighway floodplain and wetland soils.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>This option would remove fill from 300 feet of prehighway floodplain and wetland soils.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>This option would remove fill from 700 feet of prehighway floodplain and wetland soils.</td>
</tr>
</tbody>
</table>
3.3 Rocky Run Creek CEA

What are the conditions at Rocky Run Creek?

The Rocky Run Creek CEA (Exhibit 3.3-1) is located between MP 56.7 and MP 56.9. Rocky Run Creek originates above 4,800 feet elevation at Lake Lillian and flows into the east side of Keechelus Lake. The I-90 crossing over Rocky Run Creek is a 40-foot-long bridge eastbound and two 6-foot pipe culverts westbound. Overall terrestrial habitat and linkages at Rocky Run Creek have been affected by previous timber harvesting and the barrier created by Keechelus Lake.

Vegetation Community

The important habitats in the Rocky Run Creek CEA include Rocky Run Creek and riparian and forest habitats. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. Mature forest with good structural diversity is present on the south side of Rocky Run Creek. Early to mid-seral forest with low structural diversity is located on the north side of Rocky Run Creek. There are no wetlands associated with Rocky Run Creek above the reservoir and herbaceous vegetation is sparse. Upland areas are dominated by shallow soils over rocks and boulders.
Wildlife/Terrestrial Species Linkages

The Rocky Run Creek CEA provides the opportunity to link high-mobility species associated with forest, riparian, and stream habitat north of I-90 to Keechelus Lake. Although Keechelus Lake can limit the movement of species when the reservoir is full, the shoreline is available during much of the summer and fall. High-mobility species may use this area by swimming across the reservoir or using the shoreline to access habitats south of I-90.

The Rocky Run Creek CEA has the potential to provide linkage for common high-mobility species such as deer, elk, black bear, coyote, fox, and bobcat, as well as many rare species such as lynx and gray wolf. This CEA will not provide linkage for low-mobility species.

WSDOT (2002b) noted the presence of tailed frog, Pacific giant salamander, and Cascades frog in the Rocky Run Creek area. The dominant soils and the rare and/or commercially important fungi species associated with these soils are as follows (USFS 1994; USFS 2003):

- K308 Vabus Stony Sandy Loam, 45 to 65 percent slopes—Mycena overholtsii, Hellvella crassitunicata. This soil type is found in upper part of the drainage.
- K329 Kachess Gravelly Loam, 5 to 25 percent slopes—Gastroboletus turbinatus, Morchella angusticeps. This soil type is located next to I-90.
- K330 Thetis gravelly sandy loam, 25 to 45 percent slopes—Rhizopogon evadens. This soil type is found in the upper part of the drainage.

The road density in the Rocky Run Creek subwatershed is 5.8 miles of road per square mile.\(^1\) USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The public uses the Rocky Run Creek area for access to the Alpine Lakes Wilderness and Gold Creek Pond. In addition, the Gold Creek bridge adjacent to Rocky Run Creek is used as a Sno-park for motorized and nonmotorized winter sports. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

Stream Channel Function

Rocky Run Creek is a steep channel (up to 18 percent slope) that drains Naches Formation basalts on the slopes of Keechelus Ridge. The Rocky Run Creek watershed is 1,416 acres. Historically, the upper reaches of the creek were naturally confined within bedrock and colluvial deposits. As the creek entered Keechelus Lake, it probably flowed across an alluvial fan of coarse sediment.

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\(^1\) Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
This fan and the lower reaches of the creek were inundated when the Keechelus Lake dam raised the lake level. Rocky Run Creek now crosses under I-90 through two undersized culverts that block debris and cause sediment accumulation upstream of the highway.

**Wetlands**

Wetlands extend along the lakeshore south to the Keechelus Lake dam. The system is a Category II, and is a combination of open water, emergent, and scrub-shrub wetlands. Upstream of I-90, Rocky Run Creek has no wetland habitat and limited riparian areas based on the surrounding topography.

**Water Quality**

Analysis of Rocky Run Creek upstream of I-90 indicates that water quality is excellent; however, metals were detected in the creek below I-90 during snowmelt and above I-90 during a winter storm. A large proportion of the Rocky Run Creek stream length was logged without a riparian buffer prior to 1993. Daily water temperature fluctuations indicate a lack of adequate shade along the stream. Water temperatures are generally good for rainbow or cutthroat trout, although temperatures are too high for optimal bull trout rearing during summer.

**Fish Species and Aquatic Habitat Linkages**

Aquatic surveys (WSDOT 2002b) detected cutthroat trout, rainbow trout, and sculpin upstream of I-90. Additionally, a WDFW biologist observed a single bull trout in the lower reaches of Rocky Run Creek (Larry Brown, WDFW, pers. comm.). Rainbow trout observed at the waterfalls located about 750 feet upstream of I-90 may have descended (physically and genetically) from trout stocked in headwater lakes (Lake Laura and Lake Lillian).

The two pipe culverts under westbound I-90 impede fish and debris passage. Just upstream of the Forest Service Road 4832 bridge (upstream of I-90), a concrete slab in the streambed, possibly placed during construction of that bridge, may be an obstacle to upstream passage for fish. About 750 feet upstream of I-90, two waterfalls (7 feet high and 10 feet high) block upstream fish migration. Downstream of I-90, Rocky Run Creek tumbles down a long continuous riffle (12 percent gradient) into Keechelus Lake. Large substrate in this area allows small pools to form within the overall riffle, so, while fish passage is difficult through this section, it is not impossible.

A survey conducted in 2001 of the 750-foot reach noted that the average wetted width was 17.8 feet. Pool frequency (50/mile) was good, although the pool area was low (11 percent) because the step pools in this reach are small. Only one deep pool was found in the surveyed reach. Substrate in Rocky Run Creek was dominated by cobbles and boulders, and was not embedded. Large woody debris was lacking in this stream, and recruitment was reduced because of previous timber harvesting. The stream channel carries a high bedload, which may be caused in part by past logging upstream.
Rocky Run Creek is not properly functioning for aquatic linkages. Aquatic linkages are affected by the culverts at I-90, the concrete slab in the creek above I-90, and by natural waterfalls further upstream.

What are the objectives at Rocky Run Creek?

- Provide the opportunity for wildlife movement from upland to aquatic habitats and allow some seasonal connectivity when lake levels are low. The presence of Keechelus Lake and poor geographic fit limit the connectivity options at this site. Because of the presence of Keechelus Lake, this area was not considered a high priority area for high-mobility species, especially ungulates.
- Restore capacity for flood and debris flow at the Rocky Run Creek crossing structure.
- Provide fish passage for the full range of lake elevations.

What potential design options did we evaluate at Rocky Run Creek?

One design is under consideration at Rocky Run Creek (Exhibit 3.3-2). The design shown is conceptual and reflects current design at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structure, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement, and noxious weed growth and treatment requirements.

Alternatives 1 through 4

In the single option proposed for all four design alternatives for Rocky Run Creek, twin bridges, approximately 120 feet long with about 8 to 10 feet of clearance, would be constructed over the creek to provide for fish and debris passage (Exhibit 3.3-2). The gradient of the creek at this location is so steep that culverts would be barriers to fish passage; the gradient is also too steep to construct bottomless culvert structures.

How will the options perform?

Keechelus Lake is obviously an obstacle to movement by terrestrial species. Opinions differ, however, about how large an obstacle. Reviewers of drafts of this recommendation package raised questions about the appropriate level of connectivity to seek along the lake, especially when large areas of lakebed are exposed by reservoir drawdown. In response to these comments, we revisited available information about animal movement patterns, the distribution of habitats, and seasonal timing of high reservoir pool elevations that affect the functionality of CEA design options. We found that, relative to other portions of the proposed project, CEAs along the lake do not coincide with primary areas of
wildlife movement or special habitats. High pool elevations that inundate some structures near the shoreline typically last for no more than 2 to 3 months, providing some crossing opportunities during most times of the year. Consequently, we did not believe that large crossing structures would be needed in CEAs along the lake in order to meet either CEA-specific or project-wide connectivity objectives. Please see our evaluation of the Resort Creek CEA for further discussion of the roles of CEAs along the lake and the highway alignment alternatives in providing for ecological connectivity.
We found that the design concept at Rocky Run Creek would meet the hydrologic connectivity objectives at this location. The bridges would allow for the natural movement of bedload and debris in the stream; using stream simulation methods to design the proposed bridges would result in structures that accommodate fish passage needs.

This location does not coincide with primary areas of wildlife movement (steep terrain, Keechelus Lake obstacle). The Rocky Run Creek CEA is a reasonable location for a medium-size connectivity structure that would provide crossing opportunities for some terrestrial species, but not large species like ungulates or species that prefer more openness. During low reservoir pool, animals using this structure would be able to move along the lakeshore to access habitats to the south. Species capable of swimming across Keechelus Lake also could use this structure to move north and south.

See Exhibit 3.3-3 at the end of this section for an evaluation of how the single option proposed at the Rocky Run Creek CEA is likely to perform.

**Performance Standards**

Site-specific standards that apply to this CEA will be determined at a later date; see Attachment 3.

**Are there other potential restoration opportunities?**

- Improve the Forest Service Road 4832 crossing located a couple of hundred feet upstream of I-90, and remove the concrete slab upstream of the crossing without destabilizing the streambed (WSDOT 2002b).
## Rocky Run Creek Alternatives Comparison Table
### Exhibit 3.3-3

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lemkuhl (2000)?</td>
<td>1-4</td>
<td>No</td>
<td>The location of this CEA does not coincide with linkage zones and areas of animal movement, plus it is confined by steep slopes and an incised stream channel.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>1-4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>1-4</td>
<td>Yes</td>
<td>The medium crossing structure is adequately sized, but the location is suboptimal for high-mobility species movement. Rocky Run Creek has very flashy flows after precipitation events.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>1-4</td>
<td>Yes</td>
<td>Not among the primary objectives of this CEA.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>1-4</td>
<td>N/A</td>
<td>Keechelus Lake would limit habitat connectivity to the south.</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>1-4</td>
<td>Yes</td>
<td>There is little human activity in this area.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>1-4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>Hydrologic Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>1-4</td>
<td>Yes</td>
<td>Construction of the bridge would restore flood and debris flow capacity, and would remove barriers to aquatic passage.</td>
</tr>
</tbody>
</table>
### Rocky Run Creek Alternatives Comparison Table

**Exhibit 3.3-3**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>1-4</td>
<td>Yes</td>
<td>Rocky Run Creek is naturally confined within its channel, which would be spanned by a bridge.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>1-4</td>
<td>N/A</td>
<td>There are no wetlands mapped at the Rocky Run Creek crossing.</td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>1-4</td>
<td>N/A</td>
<td>There are no mapped wetlands associated with the Rocky Run Creek crossing.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>1-4</td>
<td>Yes</td>
<td>This option would restore natural surface and subsurface flow under 120 feet of roadway.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>1-4</td>
<td>Yes</td>
<td>This option would remove fill from 120 feet of riparian area.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, hydric soils, seepage zones, and groundwater recharge areas?</td>
<td>1-4</td>
<td>Yes</td>
<td>This option would remove compacted fill from 120 feet of floodplain and riparian areas.</td>
</tr>
</tbody>
</table>
3.4 Wolfe Creek CEA

What are the conditions at Wolfe Creek?

The Wolfe Creek CEA (Exhibit 3.4-1) is located between MP 57.1 and MP 57.3. Wolfe Creek originates above 4,800 feet elevation. The creek passes under I-90 in a 6-foot pipe culvert and empties into the east side of Keechelus Lake.

Vegetation Community

The important habitats in the Wolfe Creek CEA include Wolfe Creek and riparian, wetland, and mature forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. This is an area of mature forest with a relatively high amount of diversity. The understory contains multiple layers, including goatsbeard, sitka alder, vine maple, and devil's club within the shrub strata. The area downstream of I-90 is dominated by lakeshore wetland habitat.

Wildlife/Terrestrial Species Linkages

The Wolfe Creek CEA provides the opportunity to link high-mobility species associated with mature forest, riparian, wetland, and stream habitat north of I-90 to Keechelus Lake. Although Keechelus Lake can limit the movement of species
when the reservoir is full, the shoreline is available during much of the summer and fall. High-mobility species may use this area by swimming across the reservoir or using the shoreline to access habitats south of I-90.

The Wolfe Creek CEA has the potential to provide linkage for common high-mobility species such as deer, elk, black bear, coyote, fox, and bobcat, as well as many rare species such as lynx and gray wolf. This CEA will not provide linkage for low-mobility species.

Surveys of Wolfe Creek (WSDOT 2002b) indicate the presence of several amphibian and reptile species, including tailed frog and Pacific giant salamander larvae.

The dominant soils and the rare and/or commercially important fungi species associated with these soils are as follows (USFS 1994; USFS 2003):

- *Morchella angusticeps*. This soil type occurs next to I-90 in the Wolfe Creek area.

- K308 Vabus Stony Sandy Loam, 45 to 65 percent slopes—*Mycena overholtsii, Hellvella crassitunicata*. This soil type is located north of I-90 in the upper reaches of Wolfe Creek.

- K188, Chickamin Sandy Loam, 30 to 60 percent slopes—*Hericium abietis, Hygrophorous bakerensis, Gomphus clavatus, Boletus mirabilis, Ganoderma tsugae*. This soil type is located north of I-90 in the upper reaches of Wolfe Creek.

The road density in the Wolfe Creek subwatershed is 5.8 miles of road per square mile.\(^1\) The USFS has committed to reducing road densities to less than 2 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The public uses the Wolfe Creek area for recreation, primarily motorized and nonmotorized winter use. Managing recreation appropriately will be important to maintaining the area’s habitat effectiveness.

**Stream Channel Function**

The Wolfe Creek watershed is small (486 acres). Wolfe Creek drains Naches Formation basalts on the slopes of Keechelus Ridge, and is naturally confined within bedrock and colluvial deposits. Historically, as the creek entered Keechelus Lake, it probably flowed across an alluvial fan of coarse sediment. This fan and the lower reaches of Wolfe Creek were inundated when the construction of Keechelus Dam raised the lake level.

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\(^1\) Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
Today, Wolfe Creek is a very steep (more than 15 to 25 percent) confined mountain-slope channel. Upstream of I-90, Wolfe Creek is even steeper (25 percent) than below I-90 and therefore offers very little habitat for fish. Downstream of I-90, Wolfe Creek runs over an almost continuous riffle to Keechelus Lake.

**Wetlands**

Wetlands extend along the lakeshore from Gold Creek to Keechelus Dam. This system contains a combination of Category II open water, emergent, and scrub-shrub wetlands. Category II wetlands also occupy drainage ditches along the upstream side of I-90 west of Wolfe Creek.

**Water Quality**

Water quality in Wolfe Creek is excellent. The measured 7-day average daily maximum temperature never exceeded 57°F. Moderate water temperature fluctuations indicate better shading in this stream than in other project area streams.

**Fish Species and Aquatic Habitat Linkages**

Stream surveys (WSDOT 2002b) noted the presence of cutthroat trout and sculpins in Wolfe Creek. Wolfe Creek has a steep gradient of 15 to 25 percent. This limits fish habitat to a reach extending about 300 feet upstream of I-90 (WSDOT 2002b). Construction of I-90 confined the creek to a single culvert that forms a barrier to upstream fish passage. Several natural barriers and culverts under Forest Service Road 4832 further prevent passage.

In 2001, a 327-foot reach was surveyed above I-90. The average wetted width was 10 feet. Pool frequency (65/mile) was good, although the pool percentage was fair (24 percent). No deep pools were found in this small stream. Substrate was dominated by cobbles and boulders that were not embedded, and a relatively small fraction of fine sediment. Downstream of I-90, the proportion of fine sediment was higher, because this area is seasonally inundated by Keechelus Lake. Large woody debris was reasonably plentiful, and recruitment potential remains good.

Wolfe Creek is properly functioning for aquatic habitat, channel function, and water quality. Providing for fish passage under I-90 and Forest Service Road 4832 will provide access to this properly functioning habitat, but only for several hundred feet before the natural steepness of the terrain prevents fish access.

What are the objectives at Wolfe Creek?

- Restore capacity for flood and debris flow at the Wolfe Creek crossing structures.
- Provide fish passage for the full range of lake elevations. Provide aquatic organism connectivity.

**What potential design alternatives did we evaluate at Wolfe Creek?**

One design is under consideration at Wolfe Creek (Exhibit 3.4-2). The design shown is conceptual and reflects current design at the time of printing. All locations, dimensions, ground surface elevations, and culvert dimensions are approximate. Culverts will be sized to meet WDFW stream simulation requirements for fish passage.

**Alternatives 1 through 4**

In the single option proposed for all four design alternatives for Wolfe Creek, two bottomless culverts would be constructed. The proposed dimensions are 25 feet wide by 8 feet high for the westbound culvert, and 20 feet wide by 10 feet high for the eastbound culvert. These bottomless culverts would be designed to meet WDFW stream simulation requirements, as well as requirements for debris flow and fish passage. Culvert heights and widths would be optimized to facilitate wildlife movement within the constraint of the road profile and to provide a natural substrate.

**How will the options perform?**

The Wolfe Creek CEA does not coincide with primary areas of wildlife movement (steep terrain, Keechelus Lake obstacle) and does not link special habitats. Consequently, we did not develop any objectives for terrestrial wildlife connectivity at this CEA. This CEA is a reasonable location for a medium-size connectivity structure that would provide crossing opportunities for some terrestrial species, but not large body-size species like ungulates or species that prefer more openness. During low reservoir pool, animals using this structure would be able to move along the lakeshore to access habitats to the south. Species capable of swimming across Keechelus Lake also could use this structure to move north and south. Compared to the existing condition, the proposed structures would improve connectivity for some riparian species and improve linkage between upland and lakeside habitats.

Choice of a Keechelus Lake alignment could have important implications for the Wolfe Creek CEA. Construction of the long tunnel alternative and associated tunnel maintenance and ventilation facilities could affect the functionality of crossing structures here. All alternatives appear to involve placement of new fill at the mouth of Wolfe Creek and the effects of this activity on possible crossing structures is unknown at this time.

The proposed structures, common to all alternatives, would provide for hydrologic connectivity at this location. The structures would allow for the
natural movement of bedload and debris in the stream and would accommodate fish passage needs. Opportunities for restoring Wolfe Creek are restricted by the inherent limitations of such a high-gradient stream. Natural barriers and the small size of the stream limit the amount of habitat that would be made available by improved passage conditions.

**Recommended Restoration Measures**

- Improve Wolfe Creek crossing of Forest Service Road 4832 using stream simulation methods to allow for natural movement of bedload and debris in the stream, and to accommodate fish passage needs.

See Exhibit 3.4-3 at the end of this section for a comparison of the alternatives for this CEA.

**Performance Standards**

Site-specific performance standards that apply to this CEA will be determined at a later date (see Attachment 3).
Are there other potential restoration opportunities?

- Work with USBR to reduce maximum pool elevation in Keechelus Lake. Virtually all of the stream channel downstream of I-90 is seasonally inundated and provides limited habitat value (WSDOT 2002b). Reducing the maximum pool elevation could reduce sedimentation and allow for development of some riparian vegetation in the reach downstream of I-90 (see Gold Creek CEA section above).
### Wolfe Creek Alternatives Comparison Table

**Exhibit 3.4-3**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>1-4</td>
<td>No</td>
<td>The location of this CEA does not coincide with linkage zones and areas of animal movement, plus Wolfe Creek is confined by steep slopes and incised stream channel.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>1-4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>1-4</td>
<td>No</td>
<td>This would be a medium crossing opportunity. During some seasons, species that are willing to use long and low structures could pass through this structure. Wolfe Creek has very flashy flows after precipitation events.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>1-4</td>
<td>No</td>
<td>Not among the primary objectives of this CEA. It is unlikely that vegetation would develop here, and the size of the structure would limit placement of stumpwall or other structures to provide microhabitat diversity.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>1-4</td>
<td>N/A</td>
<td>Keechelus Lake limits habitat connectivity to the south.</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>1-4</td>
<td>Yes</td>
<td>There is little human use of this area.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>1-4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>Hydrologic Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>1-4</td>
<td>Yes</td>
<td>Large culverts would restore flood and debris flow capacity and would remove barriers to aquatic passage.</td>
</tr>
</tbody>
</table>
### Wolfe Creek Alternatives Comparison Table
**Exhibit 3.4-3**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>1-4</td>
<td>Yes</td>
<td>Wolfe Creek is naturally confined within its channel upstream of I-90. The design of the eastbound culvert should account for debris deposition as the steep creek transitions onto the lakeshore.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>1-4</td>
<td>N/A</td>
<td>Existing wetland flow patterns would not be altered by fish passage culverts.</td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>1-4</td>
<td>N/A</td>
<td>There are no high-value wetland resources that could be linked to Wolfe Creek.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>1-4</td>
<td>Yes</td>
<td>Flow here is driven by channel processes that are confined within Wolfe Creek. Bottomless culverts would allow channel and hyporheic flow through the streambed.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>1-4</td>
<td>Yes</td>
<td>Larger culverts would reduce the amount of fill placed in the riparian zone.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, hydric soils, seepage zones, and groundwater recharge areas?</td>
<td>1-4</td>
<td>Yes</td>
<td>Larger culverts would reduce the volume of compacted fill of Wolfe Creek.</td>
</tr>
</tbody>
</table>
3.5 Resort Creek CEA

What are the conditions at Resort Creek?

The Resort Creek CEA (Exhibit 3.5-1) is located between MP 59.3 and MP 59.7. Resort Creek originates at 4,600 feet elevation. Resort Creek flows under I-90 in a 6-foot pipe culvert, which is a barrier to fish passage, and drains into Keechelus Lake.

Vegetation Community

The important habitats in the Resort Creek CEA include Resort Creek and riparian, wetland, and mature forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. The vegetation upstream of I-90 is a mixture of emergent, scrub-shrub, and forested wetland and riparian communities that provide a diverse habitat structure. The area is subject to seasonal inundation by Keechelus Lake. Lobaria hallii, a rare lichen, was found throughout the area on large, mature cottonwood trees.

Wildlife/Terrestrial Species Linkages

The Resort Creek CEA has limited connectivity opportunities because of the location of Keechelus Lake and
topographical constraints. Keechelus Lake can limit the movement of species when the reservoir is full, but the shoreline is available during much of the summer and fall. High-mobility species may use this area by swimming across the reservoir or using the shoreline to access habitats south of I-90.

Amphibian species found at this location include Pacific giant salamander, Cascade frog, and western toad (WSDOT 2002b).

The road density in the Resort Creek subwatershed is 3.8 miles of road per square mile. The USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The public uses the Resort Creek area for recreation, primarily for motorized and nonmotorized winter use. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

**Stream Channel Function**

The Resort Creek watershed drains 1,815 acres. The upper reaches of the creek flow in a naturally confined channel, with a slope of 3.5 to 20 percent. Resort Creek flattens out as it approaches Keechelus Lake and develops an alluvial fan at its mouth. This fan, which is about 0.25 mile wide at I-90, is laced with small channels. Historically, Resort Creek would have shifted frequently across this fan as channels were blocked by sediment deposition. When the level of Keechelus Lake was raised in 1917, it inundated the lower reaches of Resort Creek and increased the rate of sediment deposition on the upper end of the alluvial fan. The construction of I-90 redirected Resort Creek to a single culvert crossing, further limiting the creek’s ability to migrate in response to sediment deposition.

Upstream of I-90, substrate is dominated by boulder, cobble, and gravel, and a relatively small fraction of fine sediment. All of the stream channel downstream of I-90 is seasonally inundated by Keechelus Lake, which limits its habitat value.

**Wetlands**

Resort Creek has a wide alluvial fan at its mouth that supports a relatively large expanse of wet meadow habitat dominated by black cottonwood. The presence of this

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1 Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
wet meadow habitat probably results from the impoundment of water when reservoir levels are high. I-90 may also act as a dike that impounds water during spring runoff. This area contains a riverine system of emergent, scrub-shrub, and forested wetlands that provide habitat for wildlife species. The wetland system was rated as a Category II under the Eastern Washington Wetland Rating System (Hruby 2004).

**Water Quality**

Temperatures measured in Resort Creek by TetraTech (2002) did not exceed state standards, with a maximum reading of 59°F. However, the monitoring period missed the warmest period of summer. Metals were not sampled at this site.

**Fish Species and Aquatic Habitat Linkages**

Aquatic surveys (WSDOT 2002b) documented the presence of cutthroat and rainbow trout upstream of I-90. About 3,937 feet of Resort Creek’s main channel and about 2,943 feet of a tributary are fish-bearing. Above these fish-bearing reaches, the creek and its tributaries become too steep for upstream passage.

The existing culvert at I-90 is a barrier to upstream fish passage except at high pool elevation, when the level in Keechelus Lake backs up through the I-90 culvert. During periods of low lake level, the outlet drops about 20 feet to boulders below. A concrete box culvert under the old roadway (upstream of I-90) is possibly a velocity barrier to upstream fish passage, although fish are found on either side of this culvert.

In the 692-foot reach surveyed above I-90 during 2001 (WSDOT 2002b), the average wetted width was 12.1 feet. Pool frequency (45.6/mile) was good, although the pool area was low (17 percent) and no deep pools were found in this small stream. Substrate was dominated by boulders and cobbles, which was not embedded. Large woody debris was plentiful, and recruitment potential remains good.

Resort Creek is properly functioning for aquatic habitat, channel function, water quality, and terrestrial habitat. The creek is not properly functioning for both aquatic and terrestrial linkages.

**What are the objectives at Resort Creek?**

- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.

- Provide a moderate level of connectivity for smaller species across the reservoir bed of Keechelus Lake during drawdown.

- Restore capacity for flood and debris flow at the Resort Creek I-90 crossing structure.
- Provide fish passage for the full range of Keechelus Lake elevations.
- Restore habitat and aquatic connectivity along the old highway alignment.
- Restore channel migration on the Resort Creek alluvial fan.
- Maintain wetland flow paths on the Resort Creek floodplain.
- Improve water quality by properly treating stormwater and highway runoff and minimizing the use of de-icer chemicals.

What design options did we evaluate at Resort Creek?

Exhibit 3.5-2 shows the designs for Resort Creek. The designs shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment. Culvert dimensions are approximate; they will be sized to meet WDFW stream simulation requirements for fish passage.

Alternatives 1 and 2

Both Alternatives 1 and 2 involve the construction of twin bore tunnels, with the eastern portals near Resort Creek. Only one design was developed for these alternatives at the Resort Creek CEA. Twin bridges with an approximate span of 120 feet and vertical clearance of 10 feet would be constructed in the eastbound and westbound directions. These bridges would span Resort Creek and the active channel migration zone upslope from the existing alignment, near the top of the Resort Creek alluvial fan.

We identified an HCZ just to the east of these bridges (Exhibit 3.5-2a). For this HCZ and all others we identified during our analysis of design options, ground-water conveyance methods will be determined after further investigation and analysis.

Alternative 3

Alternative 3 involves the construction of a single bore tunnel in the westbound direction only. Eastbound lanes would follow the existing alignment around Slide Curve along the shoreline of Keechelus Lake. Only one design was developed for this alternative at the Resort Creek CEA. This design has a single bridge with an approximate length of 120 feet and an approximate vertical clearance of 10 feet over Resort Creek in the westbound direction. A series of bottomless culverts would be constructed throughout the active channel-migration zone of Resort Creek where it crosses the eastbound lanes of I-90. At least one of these culverts would have a minimum width of 20 feet and a minimum vertical clearance of 12 feet; combined, they would span about 100 feet. Each culvert would have
Alternative 4 involves constructing the roadway around Slide Curve in both directions. Only one design was developed for this alternative at the Resort Creek CEA. A series of bottomless culverts would be constructed throughout the active channel-migration zone of Resort Creek. At least one of these culverts would have a minimum width of 30 feet and a minimum vertical clearance of 12 feet; the combined widths would span about 100 feet. These culverts would extend under both eastbound and westbound lanes, resulting in culvert lengths of about 150 feet. Culverts would be located to provide alternative crossings for Resort Creek as it shifts across its alluvial fan and would be sized to meet WDFW stream simulation requirements for fish passage.

No HCZ is included in this design.
How will the options perform?

Among the CEAs along Keechelus Lake, the Resort Creek CEA is unique because different highway alternatives are linked to specific CEA designs, with only one option for each alignment. Alignment alternatives, however, have different consequences for ecological connectivity, which influenced both our CEA-specific objectives and our evaluation of designs. Although we did not complete a detailed evaluation of how different alignment alternatives would affect ecological connectivity, we offer some general observations about how alignment alternatives influenced our evaluations of CEA options.

Twin bore tunnel alignments provide extensive connectivity along Keechelus Lake, reducing the demands on CEAs along the lake to be the main source of connectivity. Conversely, surface alignments provide limited lakeshore access, mostly at steep avalanche chutes, requiring CEAs along the lake to be the main avenues of connectivity. Tunnels are the best wildlife crossings of all because habitat is not impacted and traffic noise levels are diminished. Putting the highway in tunnels would link shoreline and upland habitats, and would provide an opportunity for high- and low-mobility species to cross over the highway. Human activity at the tunnel portals (operations, maintenance, and emergency preparedness) may affect wildlife use of the area, but even the short tunnels are long enough to provide opportunities for wildlife to move away from centers of human activity at the portals. Twin bore tunnel alignments also would have the benefit of removing the abandoned roadway, allowing restoration of shoreline and wetland habitats along the Keechelus Lake shoreline and short sections of Resort Creek downstream of the highway.

Our objectives for wildlife connectivity at the Resort Creek CEA emphasized reducing ungulate roadkill and improving opportunities for wildlife to pass around the southeast end of Keechelus Lake. Wildlife using this CEA could move into the area over the gentle terrain to the east and be directed toward the crossing by steep terrain at Slide Curve. From the south, wildlife could access the CEA by traveling over Keechelus Dam and along the lakeshore or by swimming across the lake.

The capacity of this CEA to provide ecological connectivity for high-mobility species is limited due to its steep terrain and proximity to Keechelus Lake. Relatively high rates of ungulate roadkill occur in this CEA, despite terrain conditions that suggest it is not a major movement pathway. This pattern may result from ungulates moving west along the highway from the Swamp Creek Valley until steep terrain west of Resort Creek makes them attempt a highway crossing. Crossing structures at the Bonnie and Price and Noble Creeks CEAs would likely reduce movement of ungulates into the Resort Creek area.

Low-mobility species that make smaller-scale movements may not be affected by nearby steep terrain and would benefit from improved connections between lakeshore wetlands and riparian areas north of the highway (e.g., amphibians and other species associated with riparian habitats). The combination of our
expectation that crossing structures in CEAs east of Resort Creek would reduce ungulate crossing attempts in the Resort Creek area, as well as the need for low-mobility crossing opportunities, led us to determine that this CEA warranted medium-sized connectivity structures.

Our hydrologic connectivity objectives include providing capacity for flood flows (including debris), providing fish passage, and restoring channel migration processes. Crossing structures should allow for the natural movement of bedload and debris in the stream, and should accommodate fish passage needs through use of stream simulation design methods. Because this CEA is located on an alluvial fan that forms at I-90, the crossing structures should be designed to provide for channel migration across the fan. This can be accomplished by either spanning the fan with bridges (approximately 0.25 mile wide for the lakeshore alignment), or by providing multiple, bottomless culverts along the width of the fan crossing.

See Exhibit 3.5-3 at the end of this section for a comparison of the designs for the Resort Creek CEA. To complete this comparison, we confined our evaluation of the CEA designs to performance of the CEA only. Our evaluation of the CEA was based on the anticipated road footprint because information was not available about the size and location of facilities needed for tunnel operation and maintenance. The IDT did not request that we explicitly evaluate the connectivity performance of associated highway alignments, so we did not independently conduct this comparative analysis.

**Alternatives 1 and 2**

This design, which is paired with the twin highway tunnels, would meet the connectivity needs for wildlife. Low clearance under the Resort Creek bridges may limit use by species that prefer greater openness (e.g., large ungulates), but crossing opportunities provided by the tunnels compensate for this unmet need at the Resort Creek CEA.

This design also meets the hydrologic connectivity objectives for this CEA. Alignments associated with this design would move the highway to the upper end of the Resort Creek alluvial fan, removing existing road fill from the lower end of the alluvial fan where it transitions into Keechelus Lake. This would allow the creek to migrate across its alluvial fan, and would provide for fish passage and natural movement of sediment and debris in the stream. Bridge approaches for the new alignment would place new fill in Category II wetlands east of Resort Creek (Wetland RCE). Hydrologic connectivity structures would be placed in this fill to maintain wetland flow paths through the new roadbed.

**Alternative 3**

This design could support the moderate level of wildlife connectivity that is the objective at this CEA. This finding is based in part on the flexibility afforded by preliminary designs. If one or more of the proposed bottomless culverts under the eastbound lanes can be constructed to span at least 20 feet and provide a
minimum clearance of 12 feet, then we expect that this approach would provide a crossing opportunity for occasional use by large ungulates when the reservoir is drawn down. The openness of these culverts is reduced by their 75-foot length, but our opinion is that suboptimal crossing structure attributes imposed by highway engineering constraints are acceptable at this location because it does not align with primary movement paths or special habitats. Removal and reclamation of existing roadway around Slide Curve is not anticipated with this design, limiting the potential for habitat restoration along the shoreline of Keechelus Lake.

This design meets hydrologic connectivity objectives, but provides a lower degree of alluvial fan and channel restoration than the design paired with Alternatives 1 and 2. The eastbound lanes would continue to cross the lower end of the Resort Creek alluvial fan on fill. Channel migration on the alluvial fan would be partially restored by providing multiple bottomless culverts through the roadbed that would allow the creek channel to shift location in response to sediment deposition and debris blockage. These culverts would also provide fish and debris passage. Bridge approaches for the new westbound alignment would place fill in Category II wetlands east of Resort Creek, although the area of fill would be less than in the design for Alternatives 1 and 2.

**Alternative 4**

Like the design for Alternative 3, the design associated with Alternative 4 could support moderate wildlife connectivity within the scope of preliminary designs. Our opinion is that if one or more of the proposed bottomless culverts under both directions of travel and the median can be designed to have a minimum span of 30 feet and a minimum clearance of 12 feet, then occasional wildlife crossing needs can be met when the reservoir is drawn down. The need for increased culvert spans for this design arose from the 150-foot length required in order to pass below both eastbound and westbound alignments. This design would have appreciably less openness than the other proposed structures. Removal and reclamation of existing roadway around Slide Curve is not anticipated with this design, limiting the potential for habitat restoration along the shoreline.

This design meets hydrologic connectivity objectives, but provides a lower degree of alluvial fan and channel restoration than designs associated with Alternatives 1 and 2. For this design, all lanes would continue to cross the lower end of the Resort Creek alluvial fan on fill. Channel migration on the alluvial fan would be partially restored by providing multiple bottomless culverts through the roadbed that would allow the creek channel to shift location in response to sediment deposition and debris blockage. These culverts would also provide fish and debris passage. Unlike designs for the other alternatives, this design would avoid placing new fill in wetlands east of Resort Creek (Wetland RCE), and would not need an HCZ in this location.
Recommended Restoration Measures

- For tunnel alignments, locate staging areas for tunnel construction within the footprint of the fill that would be placed for the new roadway. Outside this fill footprint, restore to their preconstruction condition all wetlands, floodplain soils, and vegetation impacted by construction (minimize and mitigate wetland impacts).

- Locate all facilities needed for operation and maintenance of tunnels outside of wetlands and the floodplain areas of Resort Creek (minimize wetland impacts and the negative effects of human activity on crossing structure performance).

Performance Standards

Site-specific performance standards that apply to this CEA will be determined at a later date (see Attachment 3).

Are there other potential restoration opportunities?

- Acquire private land near the proposed crossing structure and transfer it to public ownership. Manage acquired parcels to maintain or improve habitat integrity, and promote wildlife access to the Resort Creek crossing structure (e.g., parcels in Section 1, T. 21 N., R. 11 E.W.M. and Section 3, T. 21 N., R. 12 E.W.M.).

- Remove the box culvert under the old roadway upstream of I-90 that may be a velocity barrier to upstream fish passage (WSDOT 2002b), and replace with a grade control structure that prevents drainage of wetlands upslope from the roadbed.
Resort Creek Options Comparison Table
Exhibit 3.5-3

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>1&amp;2</td>
<td>Yes</td>
<td>This CEA does not align with high-permeability zones identified by Singleton and Lehmkuhl (2000). It may be best considered a medium crossing opportunity. For these alternatives, having the highway in a tunnel provides for high-mobility species connectivity over the tunnels, reducing the need for high clearance bridges over Resort Creek. Although the tunnels do not include the Resort Creek CEA per se, they do provide crossing opportunities adjacent to the CEA.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Yes</td>
<td>This CEA does not align with high-permeability zones identified by Singleton and Lehmkuhl (2000). It may be best considered a medium crossing opportunity. The westbound bridge would be combined with a set of culverts eastbound (10 to 30 feet bottomless). Note, at high pool, reservoir surface elevation would cross under highway.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Yes</td>
<td>This CEA does not align with high-permeability zones identified by Singleton and Lehmkuhl (2000). It may be best considered a medium crossing opportunity.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>1&amp;2</td>
<td>Yes</td>
<td>The amount of noise from tunnel ventilation is unknown. Alternative 1 would likely have higher ventilation noise, but specifics need to be determined.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>Height does not meet criteria used for large crossing structures, but the tunnels would provide nearby overcrossing opportunities with unlimited headroom.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>No</td>
<td>This alternative would provide a medium crossing opportunity; approximate culvert dimensions are 75 feet long by 12 feet high and 20 feet wide.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>No</td>
<td>This alternative would provide a medium crossing opportunity. Approximate culvert dimensions are 150 feet long by 12 feet high and 30 feet wide.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>Not a primary objective in this CEA. Bridges in both directions are higher upslope, above reservoir effects zone. The 120-foot span would likely provide terrestrial crossing opportunities.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>No</td>
<td>Not a primary objective in this CEA. During high reservoir pool levels, there would be no dry area in crossing structures. Low-mobility species opportunities would be seasonal.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>No</td>
<td>Same as Alternative 3.</td>
</tr>
</tbody>
</table>
### Resort Creek Options Comparison Table

**Exhibit 3.5-3**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>1 &amp; 2</td>
<td>N/A</td>
<td>Keechelus Lake limits connectivity to the south.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>Can be managed. Disturbance would occur at tunnel portals – both ends. Tunnel support and emergency infrastructure (e.g., fire suppression). Less effective CEA due to this disturbance. Not the best place for large investment in connectivity structures or mitigation (e.g., wetlands). Offset by ability for wildlife to move over the tunnels.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Yes</td>
<td>Same as Alternatives 1 &amp; 2.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Yes</td>
<td>No change in human activity expected in the area.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>1 &amp; 2</td>
<td>No</td>
<td>Adjacent land expected to be acquired for tunnel construction and operation.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>No</td>
<td>Same as Alternatives 1 &amp; 2.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>No</td>
<td>Purchase unlikely without need to construct and maintain tunnels.</td>
</tr>
</tbody>
</table>

#### Hydrologic Connectivity

<table>
<thead>
<tr>
<th>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</th>
<th>Alts.</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>Bridge across Resort Creek would allow natural channel functions and fish passage.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Multiple culverts would restore some channel function and complexity and would allow for fish passage. There may still be occasional maintenance needed to clear debris from culverts to provide fish passage.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Same as Alternative 3.</td>
<td></td>
</tr>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>These alternatives would provide high level of restoration of channel migration by moving the crossing to a naturally confined reach upstream of the Resort Creek alluvial fan.</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>This alternative would increase opportunities for alluvial fan channel migration by providing multiple crossing locations beneath the roadbed.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Same as Alternative 3.</td>
<td></td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroporiods?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>Hydrologic connectivity structures would be needed to avoid negative impacts on wetland hydroporiods associated with fill placed in Wetland RCE, east of the new Resort Creek bridge.</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Same as Alternatives 1 &amp; 2.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>This alternative would avoid alterations to wetland flow paths.</td>
<td></td>
</tr>
</tbody>
</table>
# Resort Creek Options Comparison Table

**Exhibit 3.5-3**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>1 &amp; 2</td>
<td>N/A</td>
<td>These alternatives do not bisect high-value wetland areas.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>N/A</td>
<td>Same as Alternatives 1 &amp; 2.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>N/A</td>
<td>This alternative does not bisect high-value wetland areas.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>Hydrologic connectivity structures would be needed to maintain wetland flow paths through fill that would be placed in Wetland RCE for the eastern approach to the new Resort Creek bridge.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Yes</td>
<td>Same as Alternatives 1 &amp; 2.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Yes</td>
<td>This alternative would restore surface and subsurface flow paths across downstream end of the alluvial fan.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>The new alignment places new fill on the floodplain of Resort Creek for the bridge approaches, but removes fill from much larger areas along the lakeshore and lower end of the alluvial fan.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>No</td>
<td>The new alignment would place substantial new fill on wetlands and floodplains east of Resort Creek.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Yes</td>
<td>Multiple bottomless culverts would reduce fill on the Resort Creek alluvial fan.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, hydric soils, seepage zones, and groundwater recharge areas?</td>
<td>1 &amp; 2</td>
<td>Yes</td>
<td>The new alignment would place new fill on wetlands east of Resort Creek, but would remove fill from much larger areas along the lakeshore and lower end of the alluvial fan.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>No</td>
<td>The new alignment would place substantial new fill on wetlands and floodplains east of Resort Creek.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Yes</td>
<td>Multiple bottomless culverts would reduce fill on the Resort Creek alluvial fan.</td>
</tr>
</tbody>
</table>
3.6 Townsend Creek CEA

What are the conditions at Townsend Creek?

The Townsend Creek CEA (Exhibit 3.6-1) is located between MP 60.5 and MP 60.7. Townsend Creek originates at about 4,000 feet elevation. The creek passes under I-90 in a 6-foot pipe culvert and empties into Keechelus Lake.

Vegetation Community

The important habitats in the Townsend Creek CEA include Townsend Creek and riparian, wetland, mature hardwood, and coniferous forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. Plant and structural diversity is high in this area. Red alder is the dominant tree species along Townsend Creek, with some big leaf maple, western redcedar, black cottonwood, Douglas-fir, and lodgepole pine. Shrub and herbaceous communities include devils club, thimbleberry, salmonberry, vine maple, red elderberry, blackcap (western or wild raspberry), lady fern, oak fern, manna grass, goat’s beard (bride’s feathers), false hellebore, feathery false lily of the valley, and Hooker’s fairy bells.
Wildlife/Terrestrial Species Linkages

The Townsend Creek CEA provides the opportunity to link species associated with mature hardwood and coniferous forest, riparian, wetland, and stream habitat north of I-90 to Keechelus Lake. Although Keechelus Lake can limit the movement of species when the reservoir is full, the shoreline is available during much of the summer and fall. High-mobility species may use this area by swimming across the reservoir or using the shoreline to access habitats south of I-90.

This CEA has the potential to provide linkage for common high-mobility species such as deer, elk, black bear, coyote, fox, and bobcat, as well as many rare species such as lynx and gray wolf. This CEA will not provide linkage for low-mobility species.

The survey and manage (USFS 1994) and commercially important fungi associated with these soils are also listed. K 330 Thetis gravelly sandy loam, 25 to 45 percent slopes: Rhizopogon evadens. This soil type is found in the upper reaches of Townsend Creek.

The road density in the Townsend Creek subwatershed is 3.8 miles of road per square mile. USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

There is limited public use at Townsend Creek based on access to the site. Motorized and non-motorized recreational activities may occur in areas near Townsend Creek. Appropriate management of recreational activities within the Townsend Creek CEA will maintain habitat effectiveness.

Stream Channel Function

The Townsend Creek watershed drains 798 acres. The upper reaches of the creek flow over Naches Formation basalts on the slopes of Keechelus Ridge, and are naturally confined within bedrock and colluvial deposits. As the creek approaches Keechelus Lake, it decreases in gradient and feeds a series of floodplain wetlands. Historically, the creek flowed across an alluvial fan and wetlands into Keechelus Lake. The I-90 roadbed covered the historical fan and confined the creek to a pipe culvert that blocks upstream fish passage, except at high pool elevation when the lake backs up through the culvert. In addition, where the creek passes under the old Sunset Highway roadway, it is confined to a concrete box culvert that fragments wetlands on the historic floodplain (WSDOT 2004b). The surveyed reach of Townsend Creek is a moderate-gradient (1.5 to 4.5 percent), moderately confined channel (WSDOT 2002b).

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1 Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
Wetlands

The Townsend Creek area between MP 60.5 to MP 60.7 is a heavily vegetated, multi-layered forest of hardwoods interspersed with some conifers. Plant biodiversity at this site is extremely high and provides good foraging opportunities for many species. Downed logs over 15 inches in diameter that provide quality habitat are present. There were multiple wetlands within the area that receive floodwaters from Townsend Creek. In addition, several of the wetlands receive hydrologic support from springs and surface flow along the old Sunset Highway between the Townsend and Price and Noble Creeks CEAs.

The area contained structural diversity and received high scores for water quality functions. Upstream of the area is a Forest Service Road and past logging activities. The wetland probably has a major function in water quality in Townsend Creek. Production and export of organic matter is also a main function based on landscape and proximity to Townsend Creek. Although the outlet is somewhat restricted, material from this wetland eventually ends up in Keechelus Lake. Habitat for amphibians is evident based on the presence of a Pacific tree frog at the site. General habitat suitability is also high, and there was evidence of elk browse in the area.

Water Quality

In a 2001 survey, temperature conditions measured in Townsend Creek were excellent (TetraTech 2002). The 7-day average daily maximum temperatures never exceeded 57°F, and daily fluctuations were very small, indicating good riparian shade through most or all of this stream. Water quality is not properly functioning due to sediment.

Fish Species and Aquatic Habitat Linkages

Cutthroat trout and sculpins were found in the reaches of Townsend Creek upstream of I-90 during surveys conducted by WSDOT (2002b). Cutthroat and brook trout, sculpins, and redside shiners were present downstream of I-90. Fish have access to a little more than a mile of Townsend Creek before the natural gradient becomes too steep (consistently more than 20 percent) to allow upstream passage of fish (WSDOT 2002b).

In the 1,252-foot reach surveyed above I-90 during 2001 (WSDOT 2002b), the average wetted width was 7.1 feet. Pool frequency (77.5/mile) and area (37.3 percent) were both good, although no deep pools were found in this small stream. Substrate was dominated by gravel and sand, with some embeddedness. Fine sediment made up a large percentage of the substrate. Large woody debris was plentiful, with good recruitment potential.

Although habitat conditions in Townsend Creek are generally good, the small size of this stream limits fish use and productivity. Aquatic habitat, channel function, and terrestrial habitat are properly functioning; aquatic and terrestrial linkages are not properly functioning due to road density in this drainage and a
seasonal fish passage barrier at I-90 when the reservoir is below full pool. During periods of low lake level, the outlet drops about 3.3 feet with no plunge pool below. All of the stream channel downstream of I-90 is seasonally inundated by Keechelus Lake and provides limited habitat value. The concrete box culvert under the old roadway (upstream of I-90) is possibly a velocity barrier to upstream fish passage, although fish are found on either side of this culvert.

What are the objectives at Townsend Creek?

- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.
- Provide a moderate level of connectivity for smaller species across the reservoir bed during drawdown.
- Restore habitat and aquatic connectivity along old highway alignment.
- Restore capacity for flood and debris flow at the Townsend Creek I-90 crossing structure.
- Provide fish passage for the full range of lake elevations.

What potential design options did we evaluate at Townsend Creek?

One design is under consideration at Townsend Creek (Exhibit 3.6-2). The design shown is conceptual and reflects current design at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Culvert dimensions are approximate. They will be sized to meet WDFW stream simulation requirements for fish passage.

Option A

Option A would install a bottomless culvert at Townsend Creek to span a width that, at minimum, would meet WDFW requirements for stream simulation, as well as requirements for debris flow and fish passage (Exhibit 3.6-2). The culvert would be sized to optimize its opening to 12 feet high and 25 feet wide to provide additional clearance for wildlife without adding fill or raising the freeway profile and to provide a natural substrate.

How will the options perform?

The single proposed crossing structure design at Townsend Creek would meet wildlife connectivity objectives at this CEA. Similar to Resort Creek, objectives for wildlife connectivity at Townsend Creek include emphasizing reduction in ungulate roadkill and improving passage opportunities around the southeast end of Keechelus Lake. Townsend Creek is near the Keechelus Dam outlet and could provide opportunities for wildlife to use the dam to cross the Yakima River.
Townsend Creek is situated next to a larger linkage zone east of Keechelus Lake that has moderate to high levels of landscape permeability (Singleton and Lehmkuhl 2000). We expect that the same species of large mammals found to the east, including deer, elk, and rare large carnivores, may occasionally move westward along the Keechelus Lake shoreline before attempting to cross the highway near Townsend Creek.

We determined that a medium-sized structure would be capable of meeting wildlife connectivity objectives at this CEA. Our rationale is similar to that for Resort Creek, namely that:

- Large connectivity structures to the east would accommodate high-mobility species moving along their normal travel paths, leading to infrequent crossing attempts by high-mobility species at Townsend Creek.

- Steep terrain to the north and partial inundation of the crossing structures under the eastbound lanes (when Keechelus Lake is at or near maximum pool elevation) would seasonally restrict crossing attempts.
Low-mobility and riparian-associated species in the vicinity of Townsend Creek would likely use a medium-sized structure.

This rationale reflects our belief that, if large crossing structures are appropriately located in this section of the project, adjacent CEAs may serve complementary functions. Although the proposed crossing structure for Townsend Creek does not conform to some of our performance standards, it would be passable by terrestrial wildlife for most of the year. If it is paired with design options at the Price and Noble and Bonnie Creek CEAs, which do meet all standards, it would be sufficient for meeting connectivity needs.

The proposed structure would provide for our hydrologic connectivity objectives at this location. The structures would allow for the natural movement of bedload and debris in the stream and would accommodate fish passage needs by using stream simulation design methods.

**Recommended Restoration Measures**

Increasing openness beyond what is provided in the current design is likely to accommodate a broader array of wildlife species in the area; therefore, we recommend optimizing the openness of the proposed crossing structure.

The hydrologic conditions in this CEA could be further improved by replacing the I-90 culvert with a bridge or a series of fish-passable structures that would allow the creek to meander.

See Exhibit 3.6-3 at the end of this section for a detailed evaluation of the design option for the CEA.

**Performance Standards**

Site-specific performance standards that apply to this CEA will be determined at a later date (see Attachment 3).

**Are there other potential restoration opportunities?**

- Acquire private land near the proposed crossing structure and transfer it to public ownership. Manage acquired parcels to maintain or improve habitat integrity, and promote wildlife access to the Townsend Creek crossing structure (e.g., parcels in Section 1, T. 21 N., R. 11 E.W.M. and Section 3, T. 21 N., R. 12 E.W.M.).

- Analyze the effects of removing portions of the Sunset Highway as a means of accomplishing wetlands mitigation and restoring the hydrologic connectivity between wetlands that have been filled and disconnected by the road.
  - Reconnect Wetlands LLW and MMW
  - Reconnect Wetlands JJW and KKW (Pierce 2005).
### Townsend Creek Option Comparison Table
**Exhibit 3.6-3**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>Bottomless culvert would be 75 feet long (split lanes). Crossing is located on the west edge of the permeability zone identified by Singleton and Lehmkuhl (2000).</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>Yes</td>
<td>Bottomless culvert dimensions are 25 feet wide by 12 feet high and 75 feet long. This structure will not provide adequate passage for large animals. It will provide passage for medium and small animals. Higher likelihood of high-mobility species crossing here compared to Resort Creek (near permeability zone) and close proximity to higher-quality habitat.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>No</td>
<td>Not a primary objective in this CEA. During high reservoir pool levels, there would be no dry area in the crossing structures. Low-mobility species opportunities would be seasonal. It is unlikely that vegetation would develop, and the size of the structure would limit placement of stumpwall or other structures to provide microhabitat diversity. Occasional low-mobility species movement would be possible along the lakeshore.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>N/A</td>
<td>Keechelus Lake limits habitat connectivity to the south.</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>Little human activity in the area – human access is difficult.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td>USFS and Bureau of Reclamation own adjacent land.</td>
</tr>
<tr>
<td><strong>Hydrologic Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>A</td>
<td>Yes</td>
<td>Larger culvert would restore flood and debris flow capacity, and would provide fish passage under most conditions. There may still be an occasional need to clear debris from the culvert to maintain fish passage since the culvert would occupy a transition in channel gradient at the lakeshore.</td>
</tr>
</tbody>
</table>
## Townsend Creek Option Comparison Table
### Exhibit 3.6-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>A</td>
<td>Yes</td>
<td>Townsend Creek is naturally confined upstream of I-90. The I-90 crossing would occupy an area where the gradient changes; the channel would tend to deposit debris here. Monitoring and maintenance would be needed to ensure fish passage.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>A</td>
<td>Yes</td>
<td>Culvert impacts would be limited to flows within the Townsend Creek channel.</td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>N/A</td>
<td>Potential linkages through the I-90 roadbed are limited to lakeshore wetlands. However, there are opportunities to improve connections between wetlands bisected by the Sunset Highway.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>Culvert provides minimal restoration of channel and subsurface flow paths in the Townsend Creek streambed.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>Yes</td>
<td>Larger culvert would reduce the amount of fill placed in the riparian zone.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, hydric soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>Larger culvert would reduce the volume of compacted fill in Townsend Creek.</td>
</tr>
</tbody>
</table>
3.7 Price and Noble Creeks CEA

What are the conditions at Price and Noble Creeks?

The Price and Noble Creeks CEA (Exhibit 3.7-1) is located between MP 60.7 and MP 61.9. The creeks drain a total of 688 acres. Price Creek crosses under I-90 in a 10-foot box culvert and drains into the Yakima River downstream of Keechelus Dam. Noble Creek crosses under I-90 in a 4-foot pipe culvert, and also ultimately flows into the Yakima River.

Price and Noble Creeks drain steep slopes made up of Naches Formation basalts and rhyolites. At the base of these slopes, the topography flattens out into a glacial terrace along the margin of the Yakima River valley. Historically, the upper reaches of Price and Noble Creeks were naturally confined within colluvial deposits. As they transitioned onto the glacial terrace, the creeks developed narrow floodplains and migrated across the terrace in response to debris blockages. The creeks may have occasionally merged before entering the Yakima River floodplain, but construction of the I-90 culverts eliminated these dynamic channel functions by confining each stream to a single culvert. Groundwater monitoring wells have been installed across the Price and Noble Creeks CEA to establish groundwater elevations and flow paths to analyze the influence of the highway on surface/groundwater interactions and design appropriate hydrologic connectivity zone (HCZ) mitigation.
This CEA includes two HCZs. The HCZ east of Noble Creek is located where small hillslope drainages formed an alluvial fan on the glacial terrace that now underlies the Price Creek Sno-park. Small channels and seeps flowed across this fan and fed shallow groundwater and possibly wetlands on the terrace at the base of the fan. Highway construction disrupted and altered these flow paths. Surface and subsurface flow from the alluvial fan was redirected into the Sno-park drainage system and conveyed into highway culverts.

The second HCZ lies west of Price Creek and extends about 800 feet along the north side of the highway where the old Sunset Highway meets I-90. This area represents a continuous complex of unconfined streams, perched wetlands, and groundwater emergence. This hydrologically active area along the north side of the highway was cut off from landforms to the south during past highway construction and placement of road fill materials. Historically, these features extended south, occupying the land upon which the highway’s existing four lanes are now located. These areas were and are important for storing both surface and groundwater, and releasing it slowly downslope toward the Yakima River, sustaining streamflow, water temperature regimes, and aquatic habitat in the Yakima River. Currently, there is some uncertainty regarding the role of I-90 and the old Sunset Highway in groundwater/surface water interactions, as well as the development and distribution of the wetlands west of Price Creek. Groundwater studies and field investigations will increase our understanding of these conditions and the restoration needs in this HCZ.

**Price Creek**

**Vegetation Community**

The important habitats in the Price Creek area (the unnamed drainage to the east of Price Creek near Keechelus Dam is also considered part of the Price and Noble Creeks CEA) include Price Creek and riparian, wetland, and mature/old growth forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. The forested area above Price Creek contains stands in early to mid-seral condition. Mature/old growth forest occurs adjacent to I-90 and Price Creek. The dominant woody plants in the area are red alder, western redcedar, and vine maple, while the dominant herbaceous plant is soft rush. Black cottonwood, red-osier dogwood, Sitka willow, salmonberry, bunchberry, twinflower, and stream violet constitute the non-dominant plants. The area connects to a large stand of mature/old growth conifer forest south of I-90. The Price Creek CEA provides the opportunity to link high quality mature/old growth forest, riparian, stream, and wetland habitats and the species associated with these habitats on both sides of I-90.
Wildlife/Terrestrial Species Linkages

The Price Creek CEA has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, lizards, salamanders, and terrestrial mollusks, as well as many rare species such as fisher, wolverine, lynx, and gray wolf.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks expected to be present in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2.

Species detected during automatic camera stations and snowtrack surveys in the general area (Singleton and Lehmkuhl 2000) include mule deer, elk, black bear, bobcat, coyote, red fox, Douglas squirrel, Northern flying squirrel, and snowshoe hare. Amphibian species observed during recent aquatic surveys included Pacific giant salamander and Cascade frog (WSDOT 2002b).

Mollusk species found during surveys at Price Creek include *Deroceras leave*, *Haplotreme vancouverense*, *Pristilium articum*, *Prophysaon dubium*, and *Vertigo columbiana*.

This CEA includes a soil type that is associated with a high diversity of rare fungi (Garvey-Darda and Worthington 2003).

In the Price Creek area, the dominant soils and the rare and/or commercially important fungi species associated with these soils are as follows (USFS 1994; USFS 2003):

- K254 Kachess gravelly sandy loam, 5 to 25 percent slopes; this soil type occurs in the Price Creek area south of I-90. Associated fungi species include *Acanthophysium farlowii*, *Boletus mirabilis*, *Boletus piperatus*, *Cantharellus subabidus*, *Dentinum repandum*, *Gomphus clavatus*, *Hericium abietis*, *Hygrocybe bakerensis*, *Laetiporus sulphuratus*, *Morchella angusticeps*, *Ramaria araispora*, *Spathularia flavida*, and *Tricholoma magnivelare*.

- K329 Kachess gravelly Sandy Loam, 5 to 25 percent slopes; this soil type occurs in the Price Creek area north and south of I-90. Associated fungi species include *Gastroboletus turbinatus* and *Morchella angusticeps*.

- K330 Thetis gravelly sandy loam, 25 to 45 percent slopes; this soil occurs north of I-90 in the upper reach of Price Creek. An associated fungi species, *Rhizopogon evadens*, also occurs in this area.

The road density in the Upper Yakima subwatershed is 3.8 miles of road per square mile (USFS 1996).¹ USFS has committed to reducing road densities to

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¹ Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The area from Keechelus Dam to the Price Creek rest area (MP 60.9 to MP 61.2) occurs within one of the three highest deer/elk roadkill concentration areas in the project boundaries. Animals appear to be channeled into this area by the topography of the Swamp Lake Valley. Collisions with elk occur during all seasons, while collisions with deer occur during the spring, summer, and fall. In the area from approximately 0.2 mile east of the Price Creek rest area to the Crystal Springs Campground (MP 61.9 to MP 62.2), a cluster of five coyote crossings was recorded in 2000, and mountain lion sign and a roadkilled mountain lion carcass were documented in 1999 (Singleton and Lehmkuhl 2000).

The recreating public currently uses the Price Creek CEA during winter as a Sno-park. There are 50 parking spaces and a high level of human activity. The presence of the Sno-park is impacting wetlands and prevents the restoration and revegetation of the area. The combination of high human use and poor habitat conditions due to the presence of the Sno-park is incompatible with species movement through the CEA. To increase the effectiveness of the crossing structure, the Sno-park should be relocated and the area restored. Outside of winter, the level of recreation in the area is considered low. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

Stream Channel Function

Price Creek has a watershed area of approximately 350 acres. Most of the watershed is well vegetated with a closed canopy. The upper watershed has areas of logging (between Forest Service Road 4832 and I-90), which have narrow buffers of small trees and vegetation surrounding Price Creek. Downstream from the project area, Price Creek flows into the Yakima River floodplain, where it joins with the Yakima River side channel.

Upstream of I-90, Price Creek flows steeply at a gradient of more than 15 percent. As it approaches I-90, the channel becomes narrow and entrenched, with localized bank erosion. This entrenchment is worsened by highway fill and channel confinement at the inlet of the I-90 culverts. Below I-90 the Price Creek culvert discharges into a shallow unconfined channel that meanders across floodplain and wetland areas on the bottom of a ravine. This ravine cuts through a glacial terrace before emptying out onto the Yakima River floodplain.

Wetlands

The Price Creek CEA contains multiple wetland complexes that have been disconnected by the I-90 corridor. A small drainage located just downstream of Keechelus Dam contains wetland habitat northeast and southwest of I-90. Hydrology of these wetlands appears to be supplied from several springs along the ridge to the east. Wetland habitat extends along a terrace from Keechelus Dam, east to the eastbound on-ramp for the Price-Noble Rest Area facility. A
large Category I wetland is located south of I-90 at the east end of the rest area. There are several small wetlands contained within the westbound Price-Noble Creek Sno-park area that were rated as Category III and IV wetlands. These wetlands are relatively low quality based on the location within the Sno-park, but they may provide water quality improvement functions.

**Water Quality**

Water quality in Price Creek is properly functioning, although fine sediment below I-90 is an issue. This sediment originates from I-90 runoff and other upstream land uses, and the accumulation of fine sediment near the Yakima side channel can be attributed to the low-gradient, forested wetland characteristics of the Yakima River floodplain.

Summer water temperatures do not exceed state standards. Price Creek exhibits a small daily range in temperatures because of the adequate shade and riparian condition. Upstream from the project area, Price Creek passes through patches of timber harvest where small, vegetated buffers remain around the creek. The creek is fairly well shaded in these disturbed areas, but the buffers do not always keep the creek well shaded.

While the temperature in Price Creek is not limiting for bull trout or other salmonids, the steep slope and reduced shade in the area of timber harvest limit the suitability of the creek for salmonids.

**Fish Species and Aquatic Habitat Linkages**

Recent fish distribution surveys were conducted when the flow downstream of I-90 was intermittent and only a few pocket pools remained. We do not know if this pattern of dewatering is a natural occurrence or a consequence of land management and roadway effects. Cutthroat trout were observed in Price Creek downstream of I-90 and no fish were observed upstream of the highway. When flow is continuous downstream of I-90, rainbow trout, brook trout, and sculpins are expected to use this stream (WSDOT 2002b).

Aquatic habitat in Price Creek is fragmented by a 24-inch culvert under Forest Service Road 4832, which is a complete barrier to fish passage at all flows, and by a long culvert under I-90, which is a partial barrier to fish passage due to its length and shallow water depth. The steep stream gradient (more than 15 percent) may also limit fish access to stream reaches above I-90.
Habitat quality varies considerably among reaches of this small stream (average wetted width of 5.5 feet). For example, riparian habitat condition is excellent downstream of I-90, fair between I-90 and Forest Service Road 4832, and good higher in the watershed. The quantity of large woody debris in Price Creek is good, contributing to good aquatic habitat complexity. Pool frequency is 37.3 per mile (moderate), but pool area is low (WSDOT 2002b).

Noble Creek

Vegetation Community
The important habitats in the Noble Creek area include Noble Creek and riparian, wetland, and mature/old growth forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. The forested areas above Noble Creek contain stands in early to mid-seral condition. Mature/old growth forest occurs adjacent to I-90 and Noble Creek. The vegetation associated with Noble Creek is red alder, Sitka willow, coyote willow, red-osier dogwood, and salmonberry. Western redcedar, white pine, soft rush, American speedwell, small-fruited bulrush, hedge nettle, vine maple, curly dock, wild ginger, sawbeak sedge, bleeding heart, trillium, and stream violet constitute the non-dominant plants within the wetland area. The area connects to a large stand of mature/old growth conifer forest south of I-90. The Noble Creek CEA provides the opportunity to link high quality mature/old growth forest, riparian, stream, and wetland habitat and the species associated with these habitats on both sides of I-90. Exhibit 3.7-2 shows an aerial view of the Price and Noble Creeks CEA.

Wildlife/Terrestrial Species Linkages
The Noble Creek CEA has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, lizards, salamanders, and terrestrial mollusks, as well as many rare species such as fisher, wolverine, lynx, and gray wolf.

Species of small mammals, amphibians, and reptiles expected to be present in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2.
Species detected during automatic camera stations and snowtrack surveys conducted by Singleton and Lehmkuhl (2000) in this area include mule deer, elk, black bear, bobcat, coyote, red fox, Douglas squirrel, Northern flying squirrel, and snowshoe hare. In addition, tailed frog and Cascades frog were found downstream of I-90 in Noble Creek.

Mollusk species found during surveys at Noble Creek include *Deroceras leave*, *Haplotreme vancouverense*, *Pristilium articum*, *Propyhsaon dubium*, and *Vertigo columbiana*.

In the Noble Creek area, the dominant soils and the rare and/or commercially important fungi species associated with these soils are as follows (USFS 1994; USFS 2003):

- **K329 Kachess gravelly sandy loam, 5 to 25 percent slopes;** this soil occurs in the Noble Creek area north and south of I-90. Associated fungi species include *Gastroboletus turbinatus* and *Morchella angusticeps*.

- **K330 Thetis gravelly sandy loam, 25 to 45 percent slopes;** this soil type occurs north of I-90 in the upper reach of Noble Creek. *Rhizopogon evadens*, an associated fungi species, also occurs in this area.

The road density in the Upper Yakima subwatershed is 3.8 miles of road per square mile (USFS 1996). USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

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1 Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
The recreating public currently uses the Noble Creek CEA during winter as a Sno-park. This use is incompatible with species movement during winter. The remainder of the year, the recreational use of the area is considered low. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

Stream Channel Function
Noble Creek has a watershed area of approximately 340 acres. Most of the watershed is well canopied and vegetated; however, areas of logging (between Forest Service Road 4832 and I-90) in the upper watershed have narrowed riparian buffers of small trees and vegetation surrounding Noble Creek. The stream gradient increases up the watershed, but less severely than at Price Creek. Gradients near Forest Service Road 4832 (above I-90) measure from 10 to 15 percent. In addition, the channel becomes narrow and confined with numerous small falls.

Highway construction artificially confined and realigned Noble Creek. Immediately upstream of I-90, the Noble Creek channel is entrenched in colluvial deposits and highway fill material. The I-90 culvert confines the channel and worsens this entrenchment. Below I-90 the culvert discharges into a shallow unconfined channel that meanders across floodplain and wetland areas on the bottom of a 100-foot wide ravine. This ravine is separated from the Price Creek ravine by a knob of high ground along the downslope side of I-90. This knob disappears as the streams approach the Yakima River floodplain.

Road drainage systems intercept and route groundwater towards Noble Creek. This causes groundwater to emerge on the east side of the creek. This flow is further influenced by subsurface and surface flow associated with an alluvial fan just east of Noble Creek. The hydrology and groundwater flow patterns across the base of this alluvial fan have been altered by compaction and highway drainage, and will need further analysis and monitoring to refine the design of hydrologic connectivity structures.

Wetlands
Historical highway construction and the Price Creek Sno-park may have interrupted wetland hydrology in the general vicinity. Surface and subsurface flow from the alluvial fan has been redirected into the Sno-park drainage system, which currently conveys water into highway culverts.

Water Quality
The MDT rated water quality in Noble Creek to be at risk because of the accumulation of fine sediment, possibly attributable to traction sand runoff from I-90 and other upstream land uses, and the accumulation of fine sediment near the Yakima River side channel attributable to the low-gradient, forested wetland characteristics of the Yakima River floodplain.
Except for a few isolated measurements, no temperature data for Noble Creek exist. The maximum temperature observed during surveys was 50°F in mid-July. The creek is well shaded below I-90, but less shaded above I-90.

Upstream from the project area, Noble Creek passes through patches of timber harvest where small, vegetated buffers remain around the creek. The creek is fairly well shaded in these disturbed areas, but the buffers do not always keep the creek well shaded. The buffers, as small as 25 feet wide (combined left and right banks), do not effectively buffer both sides of the creek. Farther up the watershed above Forest Service Road 4832, the stream enters an area of closed canopy forest that provides excellent shade and large woody debris.

Noble Creek and nearby Price Creek have very similar characteristics, including passing through the same riparian area below I-90. Therefore, Noble Creek is expected to have a similar temperature regime, with cool temperatures and low daily variability, resulting in temperature not being a limiting factor for salmonids or bull trout.

**Fish Species and Aquatic Habitat Linkages**

Noble Creek supports brook trout, cutthroat trout, and sculpins. Upstream movement of these species is blocked by complete barriers formed by the long culvert under I-90 and the undersized culvert under Forest Service Road 4832. Stream gradient varies between 10 and 15 percent, which is steep, but probably not limiting fish distribution (WSDOT 2002b).

Habitat quality varies among reaches of this stream in a pattern similar to that of nearby Price Creek. Pool frequency and area are low despite a good quantity of large woody debris, a stable channel, and good habitat complexity (WSDOT 2002b).

**What are the objectives at Price and Noble Creeks?**

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snow loads. Bridges 20 or more feet high would allow sunlight under the structures to support plant life and increase the openness of the structure.

- Build structures that would provide connectivity for at least 34 species of mammals, 8 species of amphibians, and 19 species of mollusks documented or suspected to occur in the area (see list in Attachment 2).

- Connect special soil type (K254) and the associated low-mobility species.

- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This would require wildlife fencing around the crossing structures.
- Construct wetlands and restore wetland flow paths on both sides of the highway. Removal of pavement and construction of wetlands at the Sno-Park would provide good opportunities for mitigation of project wetland impacts (pending further analysis of subsurface and surface flow patterns in this area).

- Restore flow paths and delivery of water from the alluvial fan east of Noble Creek to downslope wetlands and aquifers on the Yakima River floodplain.

- Restore capacity for flood and debris flow at the Price Creek and Noble Creek crossing structures.

- Restore channel migration and floodplain processes at Price and Noble Creeks.

- Provide passage for fish and other aquatic organisms moving throughout the stream system.

What design options did we evaluate at Price and Noble Creeks?

Exhibit 3.7-3 shows the four design options for Price and Noble Creeks. The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment.

**Option A**

Option A would construct twin bridges at the west edge of the CEA in an existing draw. These bridges would be approximately 120 feet long and provide vertical clearance ranging from 14 to 18 feet. Twin multi-span bridges, approximately 800 feet long, would be constructed over Price and Noble Creeks that would provide clearance ranging from 11 to 19 feet. Another twin multi-span bridge with approximate 1- to 4-foot vertical clearance would be constructed in the eastern 800 feet of the rest area. The Sno-park/rest area pavement structure would be removed, soils and vegetation would be restored, and wetlands would be constructed to take advantage of surface and subsurface flow from the adjacent hillslope. One HCZ was identified near MP 61, west of the 800-foot-long multi-span bridge over Price and Noble Creeks.

**Option B**

Option B would construct twin bridges at the west edge of the CEA in an existing draw. These bridges would be approximately 120 feet long and provide an approximate vertical clearance of 18 to 20 feet. Twin multi-span bridges, approximately 800 feet long, would be constructed over Price and Noble Creeks with an approximate vertical clearance ranging from 9 to 16 feet. The Sno-park/rest area pavement would be removed, soils and vegetation would be restored, and wetlands would be constructed to take advantage of surface and
Price and Noble Creeks CEA, Option A
Exhibit 3.7-3a

Price and Noble Creeks CEA, Option B
Exhibit 3.7-3b
Price and Noble Creeks CEA, Option C
Exhibit 3.7-3c

Price and Noble Creeks CEA, Option D
Exhibit 3.7-3d
subsidence flow from the adjacent hillslope. The twin multi-span bridges east of Price and Noble Creeks proposed in Option A would be replaced by an HCZ through that area. The same HCZ identified in Option A near MP 61 applies to Option B.

**Option C**

Option C would construct twin bridges at the west edge of the CEA in an existing draw. These bridges would be approximately 120 feet long with an approximate vertical clearance ranging from 14 to 19 feet. Two sets of twin bridges, approximately 120 feet long, would be constructed over both Price and Noble Creeks, with clearance ranging from 3 to 18 feet. The HCZs identified for Option B also apply here; however, the Sno-park/rest area would not be removed or restored for hydrologic connectivity.

**Option D**

Option D would construct a wildlife overcrossing (approximately 150 feet wide) across the existing rock knob on the west end of the CEA. Twin bridges, with an approximate length of 120 feet and clearance ranging from 14 feet to 19 feet, would be placed in an existing draw at the west end of the CEA. Two sets of twin bridges, approximately 120 feet long, would be constructed over both Price and Noble Creeks, with clearances ranging from 3 to 18 feet. The Sno-park/rest area pavement would be removed, soils and vegetation would be restored, and wetlands would be constructed to take advantage of surface and subsurface flow from the adjacent hillslope. The HCZs we identified for Option B also apply here.

**How will the options perform?**

The Price and Noble Creeks CEA is important for high- and low-mobility wildlife species. Based in part on high rates of ungulate roadkill in this area, we expect that topography and Keechelus Lake channel high-mobility species, especially ungulates and the large carnivores that prey on them, toward this CEA. A diverse community of low-mobility species and a special soil type are also present in the area. Consequently, our objectives for wildlife connectivity emphasized both high- and low-mobility species found in the surrounding western hemlock/Pacific silver fir plant assemblage.

To be effective for hydrologic connectivity at this CEA, crossing structures should be designed to provide for restoration of surface and subsurface flow patterns, and channel migration.

To support the development of successful final designs for crossing structures at this CEA, more information is needed in these areas:

- Groundwater monitoring and analysis to refine understanding of groundwater flow paths and the hydrologic impacts of the road prism.
- Geomorphic analysis of historic landforms and channels to determine location of natural transition from hillslope to terrace to refine designs of bridges and reconstructed channels.

- Distribution of native soils (field data) for native soils under structures.

- Dispersal and connectivity needs of target low-mobility species in this area, especially habitat conditions inside crossing structures that would optimize suitability for low-mobility species.

**Option A**

This option meets wildlife connectivity objectives. The 120-foot bridges to the west are located to take advantage of topography and wildlife travel paths, and provide high clearance necessary for year-round function for high- and low-mobility species. The 11- to 19-foot clearance range of the multi-span bridges over the creeks specified in this option nearly doubles the openness ratio relative to Option B, which should contribute to improved performance for high-mobility species. High clearance should also increase the potential for plant growth within the structure, increasing habitat continuity and the potential for successful crossings by low-mobility species. Removal of the Sno-park would minimize human activity and disturbance near the crossing structures.

This option meets the hydrologic connectivity objectives for this CEA. The multi-span bridge over Price and Noble Creeks would remove floodplain fill, allow natural channel migration, and provide aquatic organism and debris passage. The HCZ west of Price Creek would restore subsurface flow paths between wetlands and seeps along the old Sunset Highway with shallow aquifers on the Yakima River floodplain. The Sno-park would be removed to construct wetlands fed by seepage that is currently intercepted by drainage systems. The multi-span bridge at the Sno-park would provide continuous surface and subsurface flow between wetlands on both sides of the highway.

**Option B**

This option meets the wildlife connectivity objectives because of the openness ratio of this option (the length of the bridge would compensate for the lower clearances of this option). Relative to Option A, the reduced clearance of the multi-span bridges in Option B may reduce winter passage by high-mobility species due to blockage of structure entrances by snow berms, and may reduce plant development and consequently limit structure performance for low-mobility species. This option shares with Option A the positive attributes of high clearance under the 120-foot bridges to the west and removal of the Sno-park, features that should provide for adequate connectivity at this CEA.

This option meets hydrologic connectivity objectives, and is similar to Option A except that it uses an HCZ in place of the multi-span bridge at the Sno-park. This would maintain adequate hydrologic connections through the highway, but would not provide continuous wetland flow beneath the highway.
Option C

Option C does not meet the wildlife connectivity objectives. For high-mobility species, this option is deficient because of disturbance from human activity associated with retaining the Sno-park. The crossing structures over the creeks also do not have sufficient clearance to encourage use by large ungulates or to support vegetation and other habitat features that would encourage use by low-mobility species.

This option does not meet hydrologic connectivity objectives because it does not remove the Sno-park and restore natural flow paths and construct wetlands. Without this restoration, drainage systems in the Sno-park would continue to intercept upslope seepage and interrupt natural flow paths to wetlands and shallow aquifers south of the highway.

Option D

This option meets wildlife connectivity objectives. The combination of a wildlife overpass with unlimited clearance, and nearby wildlife underpasses for species that prefer greater cover may be the most effective solution for connecting populations of all terrestrial and aquatic species in this important wildlife migration corridor in the central portion of the project. Placement of these different structure types in close proximity would also provide a valuable opportunity to investigate wildlife preferences for different structure types. A “built-in” experiment of this sort eliminates confounding variables and provides a more experimental situation to test crossing structure performance (T. Clevenger, pers. comm. 2005). See discussion of the benefits of wildlife overpasses on page 2-42.

This option meets hydrologic connectivity objectives, and is similar to Option B except that Price Creek and Noble Creek would be crossed by twin 120-foot bridges. The Sno-park would be removed to construct wetlands fed by seepage that is currently intercepted by road and parking lot drainage systems. Because of high ground that separates the two creeks below the highway, these 120-foot bridges would provide similar benefits to floodplains, channel migration, aquatic organism passage, and debris passage as the multi-span bridges in Options A and B. The HCZ at the current location of the Sno-park would provide continuous surface and subsurface flow between wetlands on both sides of the highway.

See Exhibit 3.7-4 at the end of this section for a detailed comparison of the options for this CEA.

Recommended Restoration Measures

- Geomorphic analysis and bioengineering principles should be applied to design channel configurations under the Price and Noble Creek bridges that are naturally stable and tie into stream reaches upstream and downstream of the highway.
The use of retaining walls along elevated stretches of the highway and within crossing structures would be beneficial here. Retaining walls along the highway would reduce the potential for wildlife to get onto the road surface and reduce the need for exclusion fencing. Abutment walls would reduce wetland impacts, increase openness of the structure, and provide more room for placement or natural development of habitat features within undercrossing structures. Design of the retaining walls should attempt to minimize, if possible, potential impacts to subsurface flows and hydrologic processes.

To optimize connectivity improvements with any option, the existing Sno-park should be removed and the area restored to natural habitats.

Retain native soils as much as possible in this important area for surface and groundwater storage.

**Performance Standards**

All performance standards apply to the Price and Noble Creeks CEA, except Connectivity Performance Standards 4.2, 4.3, and 4.4 (see Attachment 3).

**Are there other potential restoration opportunities?**

- Construct terraced wetlands upslope from the Sno-park (Pierce pers. comm. 2005).

- Investigate and analyze the potential effects of removing the old Sunset Highway roadbed. If these analyses suggest removal of the roadbed could be accomplished in a way that is favorable to hydrologic continuity of wetlands above and below the old roadway, remove the old Sunset Highway roadbed.

- Relocate or close the Crystal Springs Campground (see Bonnie Creek and Swamp Creek CEAs), and relocate the access road (Forest Service Road 5400) to reduce human activity and its potential disturbance to wildlife attempting to use the Price-Noble crossing structures. The Crystal Springs Campground is a USFS facility located directly south of and adjacent to I-90. The campground has 30 campsites; campground use usually occurs on weekends, primarily during the spring, summer, and fall.

- Consider restoring some portion of the original hydrologic and ecological functions of the soil under the highway. This is an important surface water and groundwater storage area from which water can be released toward the Yakima River to help sustain streamflow, water temperature regimes, and aquatic habitat in the river.
## Price and Noble Creeks Options Comparison Table

**Exhibit 3.7-4**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A Yes</td>
<td>Wildlife crossing structure would be close to linkage area identified by Singleton and Lehmkuhl (2000).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A Yes</td>
<td>This option would provide a buffer, with forest regeneration, at the bridge over Price and Noble Creeks. The bridge over the unnamed creek (small creek just west of the Keechelus Lake dam) is already forested.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C Yes</td>
<td>The bridge over the unnamed creek is already forested. Retaining the Sno-park would limit opportunities for buffering at the Price and Noble Creeks crossing structure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D Yes</td>
<td>Same as Option A. The overcrossing can be designed to screen out noise and light using earth berms or walls.</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A Yes</td>
<td>The 800-foot structure over Price and Noble Creeks would double the openness ratio of Option B. Removing the Sno-park would limit human disturbance adjacent to the structure. Approximate clearance is 18 feet. West end bridges are the same for all options.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B Yes</td>
<td>Although this option does not meet the vertical clearance requirements at Price and Noble Creeks, the openness ratio of this option (the much greater length of this structure) would mitigate for reduced height. The openness ratio of this option is half of Option A.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C No</td>
<td>This option does not meet vertical clearance requirements at Price and Noble Creeks due to snow depths. It also does not meet linkage objectives because of seasonal human activity disturbance associated with Sno-park, and degradation of habitat quality due to human use and infrastructure of the Sno-park. The crossing structures at Price and Noble Creeks (two 120-foot-long structures) would be less permeable than other options. The number of individuals that can cross successfully per generation may not be sufficient to preserve genetic diversity. The openness ratio is about one-fifth of Option B, which may be adequate for ungulates, but effectiveness for carnivores is less certain.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D Yes</td>
<td>The overcrossing structure provides the greatest opportunity for year-round use by the largest number of species. Although this option does not meet vertical</td>
<td></td>
</tr>
</tbody>
</table>
### Price and Noble Creeks Options Comparison Table

**Exhibit 3.7-4**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>clearance requirements at Price and Noble Creeks due to snow depths, construction of an overcrossing would mitigate for these low clearances.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Yes</td>
<td>The structure in the CEA allows for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td>The approximate 9-foot to 16-foot clearance at the Price and Noble Creeks bridge would reduce light under the crossing and the potential for plant development compared to Option A, but the 800-foot length would broaden the lighted horizon.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>No</td>
<td>The structures would not adequately link associated habitats such as native soils and vegetation.</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Yes</td>
<td>The overcrossing can support the establishment of good habitat components on the crossing itself that would benefit low-mobility species in particular.</td>
<td></td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>Yes</td>
<td>This option would provide good connections for multiple habitat types, including good wetland continuity under the east bridge.</td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td>The wetland habitat would not be as well connected under this option.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>No</td>
<td>This option would reduce the connection of terrestrial habitat. Low-mobility species associated with some habitats in this CEA would have limited opportunity to cross here successfully because their habitats are not linked.</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Yes</td>
<td>The overcrossing structure provides the greatest opportunity for year-round use by the largest number of species, including low-mobility species (except those associated with aquatic habitats). This option would provide a high level of connectivity for species in this area because of the large number of diverse crossing structures.</td>
<td></td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>Removal of the Sno-park would reduce the amount of human disturbance in the area.</td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>No</td>
<td>The Sno-park would encourage human disturbance adjacent to the structure.</td>
<td></td>
</tr>
</tbody>
</table>
### Price and Noble Creeks Options Comparison Table

**Exhibit 3.7-4**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Is the adjacent land owned by public parties?</strong></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Yes</td>
<td>Private parcels would be far enough from the CEA to minimize potential for human use that could diminish the crossing structure’s function.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td><strong>Hydrologic Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>A</td>
<td>Yes</td>
<td>Price and Noble Creeks provide little upslope fish habitat due to steepness.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s multi-span bridge would allow natural channel migration in Price and Noble Creeks.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>This option would restore most of the active floodplain for Price Creek and Noble Creek.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option C.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>A</td>
<td>Yes</td>
<td>To avoid hydroperiod impacts, HCZ designs and locations should be refined based on groundwater monitoring and investigation of subsurface flow paths.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>N/A</td>
<td>Not applicable because of existing lower value wetlands upslope of highway. However, bridge at the Sno-park provides continuous wetland flow between potential wetland mitigation sites and Yakima floodplain wetlands.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>N/A</td>
<td>Not applicable but the HCZ at the Sno-park would restore water delivery between wetlands.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td>Not applicable but the HCZ at the Sno-park would restore water delivery to existing isolated wetlands in the Sno-park south of the highway.</td>
</tr>
</tbody>
</table>
### Price and Noble Creeks Options Comparison Table

**Exhibit 3.7-4**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>The HCZ west of Price Creek restores subsurface flow through the road bed, and restores recharge of groundwater and wetlands below the highway. The bridge at the Sno-park further restores flow paths by providing continuous natural soil under the highway. Bridge restores groundwater recharge, subsurface and surface flow on Price and Noble Creeks floodplains.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The HCZs at the Sno-park and west of Price Creek restore subsurface flow through the road bed, and improve recharge of groundwater and wetlands below the highway. Bridge restores groundwater recharge, subsurface and surface flow on Price and Noble Creeks floodplains.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option does not restore wetlands and natural surface flow paths within the Sno-park. Without wetland restoration at the Sno-park, the HCZ has only marginal function and value.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option B.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove most existing highway fill from the Price and Noble Creeks floodplains (up to 800 feet of highway). This option would also remove fill from the groundwater recharge area and emergence zone under the highway and at the Sno-park.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option does not remove fill from the groundwater recharge and emergence zone within the Sno-park.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Similar to Options A and B, but the shorter bridges would remove less fill from the Price and Noble Creek floodplains. Vertical bridge abutments or other measures should be used to ensure there is at least 100 feet of floodplain width for each creek under the highway.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove compacted fill from the groundwater recharge area and emergence zone under the highway and at the Sno-park and from the Price and Noble Creeks floodplains. There is a small amount of wetland fill at the HCZ west of Price Creek.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option does not remove compacted fill from the groundwater recharge area and emergence zone at the Sno-park. There is a small amount of wetland fill at the HCZ west of Price Creek.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>
3.8 Bonnie Creek CEA

What are the conditions at Bonnie Creek?

The Bonnie Creek CEA (Exhibit 3.8-1) is located between MP 61.9 and MP 62.5. This CEA lies in the Upper Yakima River subwatershed. Bonnie Creek drains 800 acres and flows under I-90 in a 6-foot circular metal culvert under the westbound lanes and a concrete culvert under the eastbound lanes. At I-90, the creek splits into two channels that eventually empty into the Yakima River.

Vegetation Community

The important habitats in the Bonnie Creek CEA include Bonnie Creek, a complex of bog-like wetlands, and riparian and old growth forest habitat. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. The Bonnie Creek CEA contains a diversity of wetland habitats, including remnant cedar bogs. This CEA links blocks of old growth and a complex of wetlands on both sides of I-90. The Bonnie Creek CEA provides the opportunity to link high quality old growth forest, riparian, stream, and
unique wetland habitats and the species associated with these habitats on both sides of I-90

**Wildlife/Terrestrial Species Linkage**

The Bonnie Creek CEA provides the best opportunity to link species associated with old growth forest habitat. These species are of concern throughout the Washington Cascades (USDA Forest Service 1994). Species associated with old growth include Pacific fisher, northern flying squirrel, northern spotted owl, marbled murrelet, and a diversity of rare and unique bryophytes, lichens, fungi, and vascular plants. The Bonnie Creek CEA also provides the best opportunity to connect a complex of high quality wetlands associated with a number of rare species, and the ecotone between old growth forest and wetlands.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks expected to be present in the project area, based on surveys and/or museum specimens collected in the area, are listed in Attachment 2.

Singleton and Lehmkuhl (2000) set up automatic camera stations and conducted snowtrack surveys in the general area of Bonnie Creek. Detected species included mule deer, black bear, bobcat, coyote, red fox, Douglas squirrel, northern flying squirrel, and snowshoe hare. The area upstream of I-90 provides relatively good wetland habitat adjacent to poorly defined stream channels. Pacific giant salamander and an unidentified frog were found at this location (WSDOT 2002b).

Mollusks found during surveys include *Ancotrema sportella, Haplotrema vancourversense, Deroceras leave, Ariolimax columbianus columbianus, Pristiloma articum, Prophysaon vanattae,* and *Vertigo columbiana.* *Ariolimax columbianus columbianus* and *Pristiloma articum* were also found here, as well as in the Swamp Lake area.

The dominant soil in the Bonnie Creek CEA is K259 Fluvaquents 0-2 percent slopes. This soil type is associated with two rare and/or commercially important fungi species—*Cantharellus subalbidus* and *Laetioporus sulphureus* (USFS 1994; USFS 2003).

The road density in the Upper Yakima River subwatershed is 3.8 miles of road per square mile.¹ USFS has committed to reducing road densities to less than

¹ Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

Recreational use of the Bonnie Creek area is considered low. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

**Stream Channel Function**

Bonnie Creek arises from Naches Formation basalts on the southwestern slopes of Keechelus Ridge. Historically, the lower reaches of the creek meandered across glacial deposits and flowed into a complex of wetlands before entering the Swamp Creek and Yakima River floodplains. The creek probably dissipated into multiple channels and sheet flow paths as it transitioned into this wetland complex.

Bonnie Creek is a poorly defined first-order stream that drains into the Yakima River just upstream of Swamp Creek. Bonnie Creek was mapped by the USGS in 1989 as a west fork of Swamp Creek. However, the USGS map does not reflect the current location of this channel downstream of Forest Service Road 4832. Downstream of Forest Service Road 4832, Bonnie Creek has eroded a new artificially incised channel that flows into the inlets of culverts running under I-90 west of Swamp Creek.

Much of the Bonnie Creek subwatershed is forested and provides good canopy cover. Canopy cover along the stream is approximately 50 to 70 percent. Upstream of Forest Service Road 4832, the condition of the riparian vegetation becomes more diverse in terms of both age and species. At Forest Service Road 4832, Bonnie Creek has a distinct channel and surface flow that supports cutthroat trout. Below this point, the channel enters a wetland complex, where it briefly dissipates into unconfined flow, then emerges again as two distinct first-order streams. At I-90, Bonnie Creek exists as two forks that appear to have been altered by land management, with a large portion of surface flow currently being diverted into a single channel at the east fork, where it has become channelized near the I-90 culverts.
Approximately 200 feet upstream of I-90, an abandoned road bed now captures and diverts the surface streamflow and emerging groundwater from the west fork and routes it directly to the east fork. This dewatering the west fork during portions of the water year and accelerates stream channel erosion in the east fork, contributing to streambed incision. During construction of I-90, further mechanical alteration of Bonnie Creek created two distinct, confined stream channel cross-sections with lowered streambed elevations. Currently, these two artificially confined segments of Bonnie Creek are tributaries to the Yakima River. The channelized stream was relocated into two highway culverts at the west end of the wetland complex that lies between Bonnie Creek and the Swamp Creek floodplains. The culvert inlet invert elevation in the main channel is about 15 feet lower than the surrounding wetlands at the top of the creek bank. Highway ditch systems were constructed to intercept and convey surface and subsurface wetland flow towards Swamp Creek. Bonnie Creek exhibits a highly modified stream channel geometry, with severe streambank instability continuing to produce large sediment/debris sources upstream of the I-90 culvert inlets. In addition, Bonnie Creek exhibits artificially low streambed elevations immediately upstream of I-90's embankment. Natural streambed elevations were likely modified during original highway construction to match the design elevation for the culvert inlet. Road maintenance is routinely necessary in such a system to reestablish flow through the designed culvert inlet.

Road maintenance machinery was observed excavating ditchlines in the Price and Noble and Swamp Creek CEAs in the spring of 2002 to alleviate water ponding from the highway surfaces and shoulders (Ehinger pers. comm. 2002). The east fork channel of Bonnie Creek has responded to its artificially lowered streambed elevation by headcutting a channel into wetlands upstream of I-90. About 100 feet farther upstream, the cutbanks are 10 feet high and continue for several hundred feet farther upstream until streambed incision all but disappears in a wetland complex. Downstream of I-90, Bonnie Creek remains channelized as it flows through wetlands towards the Yakima River. Before discharging to the Yakima River, Bonnie Creek flows past the Crystal Springs campground and crosses under the campground road through a 2-foot culvert.

Flow in Bonnie Creek is regulated by snowmelt, surface runoff, and groundwater discharge in the lower reach of the stream near where it crosses I-90. The stream channel is moderately steep (more than 5 percent) and confined in the upper reach, while the lower reach passes through a low-gradient (1 percent) wetland area. Streamflow is intermittent downstream of Forest Service Road 4832 and I-90.

The new, altered channel configuration correlates with highway maintenance work to divert surface water and groundwater, and aligns surface and groundwater flow toward the two I-90 culverts. Maintenance may have been necessary due to an undersized crossing structure in combination with high peak flows, groundwater saturation, and sediment and debris delivery. Intermittent flow upstream of I-90 may be a function of a lowered groundwater elevation.
associated with the lowered streambed elevation through the wetland area, reducing late season flow contributions.

In addition to conveying surface flow from upslope through the roadway, the two existing culverts at I-90 and road ditches are influencing wetland hydrology.

**Wetlands**

The Bonnie Creek area has Category I wetlands. Bonnie Creek’s modified channels bisect these wetlands, intercepting groundwater from both streambanks, as well as from the highway ditch line along the north side of I-90. The bottom of the ditch line is at a lower elevation than the wetland surface elevation immediately upslope. This alters the hydraulic gradient, lowering the local groundwater table and degrading the wetland by shortening the hydroperiod. The streambanks are unstable and eroding as a result of the lowered streambed elevations.

The I-90 roadbed blocks surface and subsurface flow from wetlands east of Bonnie Creek, and redirects this flow into ditches that drain towards Bonnie and Swamp Creeks. The wetlands at the Bonnie Creek CEA were not created by the highway construction. The existing I-90 configuration and associated maintenance activities have altered surface and groundwater flow paths, degraded wetland functions, and disconnected wetlands on both sides of the highway. The lowering of the Bonnie Creek streambed upgradient of the highway during I-90 construction may have resulted in lowering the groundwater levels and the gradient in the vicinity of the creek. HCZs have been delineated in this CEA to emphasize the importance of restoring Bonnie Creek’s unconfined stream channel characteristics, floodplain function, wetland hydrology and connectivity, and water quality. Saturated conditions associated with the wetland areas on either side of the channels contribute to bank collapse and sediment delivery into the channel. Groundwater monitoring wells have been installed in the Bonnie Creek CEA to establish groundwater elevations and flow paths to analyze the influence of the highway on surface/groundwater interactions and to design appropriate HCZ mitigation measures.
Water Quality

Water quality data were not collected in Bonnie Creek. However, Ehinger (pers. comm. 2002) observed traction sand and sediment accumulation in the channels near I-90.

While the substrate size distribution is predominantly gravel and cobble, with some fines, the streambank materials in the lower reach (above the I-90 culvert) are dominated by silt and clay materials.

Fish Species and Aquatic Habitat Linkages

Cutthroat trout was the only fish species found in Bonnie Creek. Aquatic habitat in this creek is fragmented by subsurface flow as well as impassible culverts under I-90. Above Forest Service Road 4832, Bonnie Creek has limited but continuous surface flow. Downstream of 4832, Bonnie Creek occupies a new, poorly defined channel that dissipates into wetlands about 500 feet upslope of I-90. High peak flows and sediment aggradation associated with timber harvest in the Bonnie Creek watershed may be responsible for the altered channel location and discontinuous flow (WSDOT 2002b). Downstream of I-90, Bonnie Creek resurfaces and flows through a 2-foot culvert under a road in the Crystal Springs campground. We do not know if this culvert is a barrier to fish passage at some flows.

A detailed habitat survey of Bonnie Creek was not done because of lack of surface water connection to the Yakima River. Canopy cover over the continuous stream channel above Forest Service Road 4832 is 50 to 70 percent. Stream gradient is between 1 and 5 percent (WSDOT 2002b).

What are the objectives at Bonnie Creek?

- Provide a high level of year-around connectivity for high- and low-mobility species associated with this CEA. Year-round connectivity would require high structures because of winter snow loads (12-foot clearance plus 4-foot average snowpack, for a total minimum clearance of 16 feet). Bridges over 20 feet high would provide light under the structures that would support plant life and increase the openness of the structure.

- Build structures that would provide connectivity for at least 35 species of mammals, 8 species of amphibians, and 17 species of mollusks associated with Pacific silver fir/western hemlock habitats documented or suspected to occur in this area (see list in Attachment 2).

- Provide connectivity for late-successional habitat and species present in this area.

- Consider providing arboreal crossing structures for flying squirrels and other arboreal species.
- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This would require wildlife fencing around the crossing structures.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Restore natural streambed elevations, channel, floodplain, and wetland flow paths at both forks of Bonnie Creek.
- Minimize the need for destructive channel maintenance by providing crossing structures with proper grade and capacity.

**What design options did we evaluate at Bonnie Creek?**

Exhibit 3.8-2 shows the options designed for Bonnie Creek. The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment. Culvert dimensions are approximate. They will be sized to meet WDFW stream simulation requirements for fish passage.

**Option A**

Option A would construct twin multi-span bridges across Bonnie Creek and a fork 300 feet to the west. The bridges would be approximately 600 feet long and would provide vertical clearance ranging from 20 feet to 29 feet. One HCZ was identified 500 feet east of the proposed bridge (Exhibit 3.8-2a).

**Option B**

Option B would construct twin multi-span bridges across Bonnie Creek, approximately 240 feet long, that would provide vertical clearance ranging from 19 to 22 feet. This bridge is aligned primarily with wetland habitat. Two HCZs were identified, one 500 feet east of the proposed bridge and other at the west fork of Bonnie Creek (Exhibit 3.8-2b). The HCZ for the west fork of Bonnie Creek would include a bottomless culvert approximately 10 feet wide.

**Option C**

Option C would construct a bottomless culvert at Bonnie Creek approximately 16 feet wide by 10 feet high (Exhibit 3.8-2c). The same HCZs identified for Option B also apply to this option.
Bonnie Creek CEA, Option A
Exhibit 3.8-2a

Bonnie Creek CEA, Option B
Exhibit 3.8-2b
How will the options perform?

The Bonnie Creek CEA provides one of the best opportunities to provide linkages for old growth forest habitat and species associated with this habitat. Wildlife connectivity considerations here are similar to the Price and Noble Creeks CEA and include providing year-round connectivity for high- and low-mobility species and reducing ungulate roadkill. Complex vertical structure of old growth forest in this CEA also provides an opportunity to link arboreal species.

Bonnie Creek and Swamp Creek and their associated wetlands form a complex subsurface and surface flow system that interacts with alluvial aquifers and wetlands in the Yakima River floodplain. Hydrologic objectives at the Bonnie Creek CEA include restoring historical unconfined flow patterns, channel gradients, and wetland flow paths at both forks of Bonnie Creek to enhance wetland functions and connectivity with the Yakima River floodplain.

More information is needed to refine the designs at this hydrologically complex CEA, including:
Groundwater dynamics; monitoring and modeling will be needed to fully understand 2- and 3-dimensional flow patterns in this area to refine the designs and locations of HCZs.

Channel restoration and bioengineering options that can be used to recreate natural unconfined flow near the new bridge crossing structures.

**Option A**

The MDT found that the design concept for Option A would meet wildlife connectivity objectives at this location. This option best links species using old growth forest habitat (e.g., pine marten, fisher, northern flying squirrel, Pacific shrew) because it is centrally located in the remaining old growth habitat patch, and increased openness provided by the long span and high clearance would likely increase both the potential for use by many species and its winter performance. The extensive span of this structure would also allow it to partly overlap wetland habitat, providing crossing opportunities for species associated with this habitat type (e.g., Cascades frog, beaver, water vole). This is particularly beneficial because this option would allow connectivity for wetland and old growth habitat together, which is likely to encourage use by a large variety of species.

This option meets the hydrologic connectivity objectives for this CEA. The multi-span bridge would restore unconfined flow and wetland flow paths at both forks of Bonnie Creek. The longer bridge span, along with in-channel streambed restoration work, would restore the natural streambed elevations and grade of the Bonnie Creek. This would reduce channel headcutting that is degrading wetlands upslope of the highway and would reestablish overbank flooding into the adjacent wetlands to restore the wetland hydroperiod. The new structure would also provide aquatic organism passage and eliminate the need for destructive channel maintenance. An HCZ east of the bridge would restore natural flow paths between wetlands and shallow groundwater on both sides of the highway.

**Option B**

Option B's bridge is aligned primarily with wetland habitat. This option provides a 19- to 22-foot-high multi-span terrestrial crossing structure that would be aligned primarily with wetland habitat. Although this crossing structure would be adjacent to old growth and therefore might function adequately for some high-mobility species associated with old growth, it would not function as well for low-mobility old growth-associated species because they would need to move into wetland habitat to access the crossing structure. Option B does not provide adequate representation of old growth habitat or unique wetlands, or the ecotone between them, to ensure connectivity of the species associated with these habitats.

This option partially meets hydrologic connectivity objectives. The 240-foot bridge would restore wetland flow paths, provide aquatic organism passage, and eliminate the need for destructive channel maintenance at the east fork of Bonnie
Creek, but not the west fork. Vertical abutments should be used to maximize floodplain and wetland width beneath the bridge. An HCZ would partially restore unconfined flow, channel gradients, and sediment movement at the west fork, but would likely not be sufficient for restoration of natural channel migration in the event the recommended upslope restoration work on the abandoned roadbed was completed. This HCZ would be unique from others in the project area as it would require a minimum 10-foot-wide, bottomless culvert at the west fork to accommodate channel migration.

Option C

This option does not meet wildlife connectivity objectives. The bottomless culvert in Option C would be fish passable, but would not provide clearance and openness adequate for high-mobility species and would not support the habitat components within the crossing that are expected to encourage use by low-mobility species.

This option would not meet hydrologic connectivity objectives, primarily because the culvert at the east fork would confine and concentrate flow from wetlands associated with Bonnie Creek. The new structure would allow for fish passage, but would not eliminate the ongoing need for destructive channel maintenance at the culvert inlet.

See Exhibit 3.8-3 at the end of this section for a detailed evaluation of the options for this CEA.

Recommended Restoration Measures

The abandoned roadbed, which is located approximately 200 feet upslope and parallel to I-90, would be scarified to break up soil compaction and recontoured to match adjacent landform configuration to restore natural surface and subsurface flow paths in the forks of Bonnie Creek.

To the north of I-90, recreational use of Bonnie Creek is considered low. To the southeast of I-90, the Crystal Springs Campground borders Bonnie Creek. Human use of Crystal Springs Campground is fairly limited and is mostly used on weekends during the summer months. Ideally, the Crystal Springs Campground should be closed to increase the effectiveness of crossing structures in this location. As part of the coordination for the project, USFS is urged to consider special management or moving this campground to adjacent land where road access and human use would have less effect on habitat linkages and disruption of hydrologic connectivity.

Performance Standards

All performance standards apply to the Bonnie Creek CEA (see Attachment 3).
Are there other potential restoration opportunities at Bonnie Creek?

- Relocate or close the Crystal Springs Campground and relocate the access road (see Price and Noble Creeks CEA section).

- Closure of this campground would facilitate realignment of the existing access road that bisects Wetland GE. Realignment of Forest Service Road 5400 could enhance the effectiveness of both Bonnie Creek and Swamp Creek crossing structures by eliminating the need for wildlife to cross the surface of this access road as they approach I-90 from the south.

- If realignment of Forest Service Road 5400 is not feasible, increasing the potential for water to move through the roadbed (longer bridges, more and larger culverts) would benefit Swamp Creek and associated wetlands.

- If the Crystal Springs Campground and access road are not closed, the Bonnie Creek culvert and road fill in the campground should be examined to determine if it is a barrier to fish passage, and if it is, replaced with a culvert designed using WDFW stream simulation methods.

- Restore the large gravel mining area that has been largely denuded of vegetation. This patch of unsuitable habitat may discourage some wildlife that approaches I-90 from the south from reaching and using the Bonnie Creek and Swamp Creek crossing structures.
### Bonnie Creek Options Comparison Table

**Exhibit 3.8-3**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>This CEA has the highest old growth forest habitat permeability.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Placement is at edge of focal habitat type.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Placement of structure does not align with focal habitat.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td>Old growth development and high clearance helps.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option has the potential to buffer traffic disturbances. The location closer to wetlands would be less buffered by native vegetation.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>This option would be less noisy due to a bottomless culvert (vs. a bridge) and would be easier and less costly to mitigate due to the small structure size. The location closer to wetlands would be less buffered by native vegetation.</td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>Yes</td>
<td>This option would link interior forest species, and the structure is wide enough to support “interior-like” conditions.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>This option would not provide adequate linkage for old-growth-associated species.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option would not provide adequate linkage for old-growth-associated species.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>Yes</td>
<td>This option would link interior forest species, and the structure is wide enough to support “interior-like” conditions.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>Bridge alignment would not provide sufficient terrestrial habitat to link low-mobility species associated with old-growth habitat.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>The 10-foot bottomless culvert would reduce light under the crossing and potential for plant development.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>Yes</td>
<td>This option would link interior of forest as well as the wetland and edge habitats, providing good connections for all the habitats in this CEA.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>This option does not directly connect interior forest (focal species for this CEA), but does link wetlands and edge between forest and wetland habitats.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Only wetland habitat, not edge or old growth (focal habitat of this CEA).</td>
</tr>
</tbody>
</table>
### Bonnie Creek Options Comparison Table
**Exhibit 3.8-3**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>The Crystal Springs Campground and access road could discourage wildlife use of connectivity structures. Closing this campground or limiting to day use would maximize the effectiveness of the wildlife crossings.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td>Private parcels are sufficiently distant from the CEA to minimize potential for human use to diminish crossing structure function.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Hydrologic Connectivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>A</td>
<td>Yes</td>
<td>The bridge would restore natural aquatic habitat and channel functions in both forks of Bonnie Creek, and would remove a fish passage barrier at I-90.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>The culvert at the west fork of Bonnie Creek would remove the fish barrier at I-90, but would not restore natural channel functions.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>The culverts at the east and west forks would remove fish barriers, but would not restore natural channel functions.</td>
</tr>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s wide span would allow natural channel migration of both forks of Bonnie Creek, which would allow these channels to evolve toward the historical multi-channel and diffuse wetland flow system.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>Bridge at the east fork of Bonnie Creek would restore natural channel gradients and unconfined flow patterns, however, the HCZ would only partially restore channel migration for short-term.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Culverts would confine both forks within artificial channels. Ditching and dredging would still be needed to maintain the inlet channels.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>A</td>
<td>Yes</td>
<td>The bridges would restore natural upslope hydroperiods on both forks.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The bridge on the east fork of Bonnie Creek would restore natural hydroperiods upslope. The culvert and HCZ at the west fork would maintain current conditions.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>The culverts would maintain existing wetland flow conditions at both forks.</td>
</tr>
</tbody>
</table>
### Bonnie Creek Options Comparison Table

#### Exhibit 3.8-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>Yes</td>
<td>The long span over both forks of Bonnie Creek would provide continuous wetland flow between high-value wetlands on both sides of the highway.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The span over the east fork of Bonnie Creek would provide continuous wetland flow between high-value wetlands on both sides of the highway. The HCZ at the west fork would not provide continuous wetland flow for upslope wetland areas that may have been drained by the existing culvert.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option does not provide a continuous link between high value wetlands on either side of the highway at the east fork of Bonnie Creek.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>The long span over both forks of Bonnie Creek would restore diffuse wetland flow and shallow subsurface flow through the highway.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Bridge at the east fork of Bonnie Creek and the HCZ at the west fork would restore diffuse wetland flow and shallow subsurface flow through the highway.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>The culvert at the east fork of Bonnie Creek would not restore surface and subsurface flow patterns between wetlands on either side of the highway. HCZ at the west fork partially restores flow patterns, but still confines wetland and seepage flow within a channel.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove existing highway fill from 600 feet of floodplain at both forks of Bonnie Creek.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option would remove existing highway fill from 240 feet of floodplain at the east fork of Bonnie Creek. Vertical abutments should be used to maximize floodplain and wetland width beneath the bridge.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Under this option, floodplain fill would remain at both forks of Bonnie Creek.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove compacted fill from 600 feet of historical floodplain and wetlands at both Bonnie Creek forks.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>There would be a net reduction of compacted fill due to removal from 240 feet of historical floodplain and wetlands at the east fork of Bonnie Creek. This option does not remove fill from fill in wetlands at the west fork.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option does not remove compacted fill from historical floodplains and wetlands at either Bonnie Creek fork.</td>
</tr>
</tbody>
</table>
3.9 Swamp Creek CEA

What are the conditions at Swamp Creek?

The Swamp Creek CEA (Exhibit 3.9-1) is located between MP 62.5 and MP 63.4. Located in the upper Yakima River subwatershed, Swamp Creek drains 2,570 acres and flows under I-90 in an 8-foot double box culvert that drains into the Yakima River. The Swamp Creek CEA includes several HCZs that link wetlands east of Swamp Creek and near the Stampede Pass interchange to wetlands and shallow aquifers on the Yakima River floodplain.

Vegetation Community

The important habitats in the Swamp Creek CEA include Swamp Creek, Swamp Creek wetland, and riparian and old growth forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. This CEA includes a soil type that is associated with a high diversity of rare fungi (Garvey-Darda and Worthington 2003). The Swamp Creek CEA contains wetland habitats, including remnant cedar bogs. This CEA links contiguous blocks of old growth and a complex of wetlands on both sides of I-90. The Swamp Creek CEA provides the
opportunity to link old growth forest, riparian, stream, and unique wetland habitats and the species associated with these habitats on both sides of I-90.

**Wildlife/Terrestrial Species Linkages**

The Swamp Creek CEA has the potential to provide important linkage between unique wetland/marsh habitats, and associated species such as common garter snake, western terrestrial garter snake, northwestern salamander, Cascades frog, western toad, long-toed salamander, and a number of aquatic and terrestrial mollusk species. The Swamp Lake area and associated bog-like wetlands are known for a number of rare plants and a diversity of rare fungi. This CEA has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, lizards, salamanders, and terrestrial mollusks, as well as many rare species such as Fisher, wolverine, lynx, and gray wolf. Exhibit 3.9-2 shows an aerial view of the Bonnie Creek, Swamp Creek, and Toll Creek CEAs.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks expected in the project area, based on surveys and/or museum specimens collected in the area, are listed in Attachment 2.

Singleton and Lehmkuhl (2000) documented river otter using a large box culvert at Swamp Creek. In the area between the Stampede Pass and Cabin Creek exits (just east of Swamp Creek at MP 63.3 to MP 63.7 in the Toll Creek CEA), three bobcat and five coyote crossings were recorded during the two winters of snowtracking. The species detected from automatic camera stations and snowtrack surveys in the general area include mule deer, elk, black bear, bobcat, coyote, red fox, Douglas

![Western toad](image_url)

**Area of Bonnie Creek, Swamp Creek, and Toll Creek CEAs**

Exhibit 3.9-2
Long-Nose Dace

squirrel, northern flying squirrel, and snowshoe hare. Surveys within the Swamp Creek CEA were limited because of private land ownership upstream of I-90. The creek has been dammed and provides no upstream access for fish. The downstream portion flows into a large wetland complex that ultimately connects to the Yakima River. It is likely that the wetland areas downstream would provide habitat for those species identified in the upstream reach of Swamp Creek. Upstream of I-90, surveys documented the presence of brook trout, long-nosed dace, Cascade frog, and western toad.

Swamp Lake is about a half-mile east of I-90 and is the main source of Swamp Creek. It encompasses a large scrub-shrub and forested wetland with a small emergent component. It provides high-quality habitat for pond-breeding amphibians, including northwestern salamander, rough-skinned newt, western toad, Cascade frog, Pacific tree frog, and long-toed salamander. All these species are at risk of roadkill during the breeding season, when they migrate to ponds, and when they leave the ponds after metamorphosis.

Mollusks found during surveys include Ancotrema sportella, Haplotrema vancouverversense, Deroceras leave, Ariolimax columbianus columbianus, Pristiloma articum, Prophysaon vanattae, and Vertigo columbiana. Ariolimax columbianus columbianus and Pristiloma articum were only found in the Swamp Lake and Bonnie Creek areas.

In the Swamp Creek area, the dominant soils and the rare and/or commercially important fungi species associated with these soils are as follows (USFS 1994; USFS 2003):

- **K254** Kachess Gravelly sandy loam, 5 to 25 percent slopes. Associated fungi species are Acanthophysium farlowii, Boletus mirabilis, Boletus piperatus, Cantharellus subabidus, Dentinum repandum, Gomphus clavatus, Hericium abietis, Hygrophorus bakerensis, Laetiporus sulphureus, Morchella angusticeps, Ramaria araispora, Spathularia flavida, Tricholoma magnivelare. This soil type occurs in the Swamp Lake and Swamp Creek areas.

- **K329** Kachess Gravelly Sandy Loam, 5 to 25 percent slopes. Associated fungi are Gastroboletus turbinatus and Morchella angusticeps. This soil type occurs next to Swamp Creek north of I-90.
The road density in the Upper Yakima subwatershed is 3.8 miles of road per square mile.¹ USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

Recreational use in the Swamp Creek CEA includes a high level of motorized and nonmotorized winter use. Traffic levels on Kachess Road to the Kachess Campground are also high year-round. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

**Stream Channel Function**

Swamp Lake is impounded by a glacial moraine and is underlain by bog deposits and alluvium. Swamp Creek cuts through the crest of this moraine and meanders through glacial deposits before entering the Yakima River floodplain below I-90. Near I-90, the creek cuts a relatively confined channel through glacial deposits before transitioning onto the Yakima River floodplain. Historically, the mouth of Swamp Creek was likely a dynamic mosaic of channels and wetlands that shifted in location and configuration as the Yakima River migrated across its floodplain.

Flood storage by Keechelus Dam has altered the hydrology of the Yakima River and reduced the river’s rate of migration across its floodplain at the mouth of Swamp Creek. The 100-year floodplain of the Yakima River extends upstream along Swamp Creek to the upgradient side of I-90. Construction of I-90 on fill across the Swamp Creek and Yakima River floodplains has limited interactions between the two floodplains.

Swamp Creek is now confined within a series of culverts under I-90, Kachess Lake Road, and Forest Service Road 54. A small private dam immediately upstream of I-90 blocks the channel and creates a seasonal pond.

The highway has compacted the floodplain. Under natural conditions, there was a high level of connectivity between surface water and groundwater in the Swamp Creek area, linking wetlands and shallow groundwater to the Yakima River floodplain. Roadfill from I-90, Forest Service Road 54, and the small, private dam constructed upstream of I-90 are partial barriers to hydrologic continuity. In addition to the I-90 roadfill, ditches disrupt natural flow paths, wetland hydrology, and hydrologic connectivity between wetlands and landforms on either side of the highway. Highway drainage facilities intercept surface runoff and groundwater, redirecting it in ditches alongside the roadway before discharging it either directly into Swamp Creek or through narrow drainage culverts. Future construction is expected to further alter these flow paths. HCZs have been delineated throughout the Swamp Creek CEA to emphasize areas of

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¹ Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
importance in restoring floodplain function, wetland hydrology, and hydrologic connectivity throughout this area.

Groundwater monitoring wells have been installed in the Swamp Creek CEA to establish groundwater elevations and flow paths to analyze the influence of the highway on surface/groundwater interactions and to design appropriate HCZ mitigation. Field observations (Martin 2005) have raised questions about the value of the HCZ at the westernmost end of the Swamp Creek CEA. Further analysis of the topography and groundwater levels in this area is needed to determine the value of placing an HCZ in this location. At the eastern end of the CEA, observations indicated that while some groundwater was seeping beneath the existing road prism, the natural flow paths had been considerably altered by WSDOT maintenance facilities and existing highway drainage structures. Mitigation actions in this area should reestablish the groundwater flow down and across the Swamp Creek valley.

The surveyed segment of Swamp Creek between I-90 and the Yakima River had a low gradient of 2 percent, with significant off-channel habitat below I-90. Below I-90, Swamp Creek approaches the Yakima River floodplain in a complicated network of channels, wetlands, and ponds, making it difficult to measure large woody debris and pool frequency. Fine sediments were high in Swamp Creek due to its wetland/pond characteristics, and substrates were often embedded. The stream is moderately well canopied, but clearing from development and open-water wetlands and ponds are present. Instream cover was moderate and primarily overhanging vegetation (vine maple and grasses).

**Wetlands**

Historically, a series of wetlands east of Swamp Creek flowed across a glacial terrace into the Yakima River floodplain, recharging floodplain wetlands and shallow groundwater. Highway drainage ditches at the Stampede Pass interchange now intercept some of this flow and convey it into drainage culverts. Fill placed for a log scaling yard and the WSDOT stockpile area eliminated portions of these wetlands and further altered wetland flow paths.

Today, the Swamp Creek CEA has a number of hydrologic features on both the east and west sides of the Stampede Pass/Crystal Springs interchange. West of Swamp Creek, a 25-acre Category I wetland complex extends along the north side of the highway. Swamp Creek and its floodplain occupy the east side of this wetland complex, flowing beneath I-90 in a 250-foot-long double concrete box culvert that artificially constricts flow and limits floodplain function. South of the highway, Swamp Creek flows through a 4-acre Category II wetland for approximately 500 feet before reaching Forest Service Road 54, where it passes through a set of 57-foot-long double concrete box culverts enroute to the Yakima River. This Category II wetland is believed to have been historically connected to off-channel wetland features and the floodplain of the Yakima River.
East of the Stampede Pass/Crystal Springs interchange, a series of small Category I, II, and III wetlands occupy the north side, and, to a lesser extent, the south side of the highway. One small stream channel flows from the wetlands north of the interchange, flowing from the east end of the WSDOT traction sand stockpile area next to the parking area immediately adjacent to the westbound off-ramp.

Hydrologic connectivity between the wetlands on either side of I-90 is an important value in this CEA due to the scale of the wetlands, their position relative to the Yakima River, and their value in regulating water quality, streamflow, and aquatic ecosystem function of the Yakima River.

**Water Quality**

Summer water temperatures in Swamp Creek commonly exceed state standards, which may limit the distribution and success of salmonid fish, especially bull trout (TetraTech 2002). During July 2001, a maximum water temperature of 66.5°F was recorded, and 7-day average temperatures commonly exceeded 60°F. Swamp Creek exhibits a large daily range in temperatures because the substrate has a high proportion of fine sediment, which indicates inadequate riparian function along Swamp Creek above I-90. This condition is similar to other creeks in the floodplain. Measurements taken downstream of I-90 also indicate high levels of fecal coliform bacteria.

The substrate below I-90 consists of primarily gravel and cobble with moderate to high levels of fine sediments, especially at I-90, and within the forested wetland of the Yakima River floodplain. Substrate particle distribution measurements taken in two locations, one upstream of I-90 and one downstream, exhibited a high proportion of fine sediment. Although road runoff may contribute to the fine sediments in this stream, organic material generated in the extensive wetlands associated with this stream are a more significant source of fine sediment.

The MDT rated overall water quality in Swamp Creek as not properly functioning. Specific contributing factors include temperature (due to poor riparian vegetation upstream of I-90), sediment (from the highway and from the WSDOT sand stockpile), fecal coliform, and the presence of lead in stormwater runoff.
Fish Species and Aquatic Habitat Linkages

Surveying within the Swamp Creek floodplain was not possible, but conditions are good for fish rearing because of the large number of wetlands, vegetation, good shade, and cover. Cutthroat trout, rainbow trout, brook trout, and sculpins are expected to occur in Swamp Creek. Culverts under I-90, Kachess Lake Road, and Forest Service Road 54 allow fish passage, but a small dam and blocked culvert immediately upstream of I-90 are barriers to fish passage.

Large woody debris is almost absent from Swamp Creek. Below I-90, Swamp Creek converges with the Yakima River through a complicated network of channels, wetlands, and ponds within the Yakima River floodplain, which results in good habitat complexity, even with the lack of large woody debris. Riparian vegetation is well developed within the floodplain, but poorly developed above I-90. Above I-90, habitat complexity is low due to roads, development, and historical logging activities. The MDT determined the Swamp Creek area’s aquatic habitat to be at risk due to the poor riparian system, road density in the area, public and private development, and logging.

What are the objectives at Swamp Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the Pacific silver fir/western hemlock species assemblage zone. Year-round connectivity would require high structures due to winter snowpacks (12-foot clearance plus 4-foot average snowpack, for a total minimum clearance of 16 feet). High structures would provide light under the structures to support plant life and increase the openness of the structure.

- Build structures to provide connectivity for at least 36 species of mammals, 10 species of amphibians, and 21 species of mollusks documented or suspected to occur in the area (see list in Attachment 2).

- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk.

- Connect special soil type (K254) and the associated low-mobility species.

- Provide passage for fish and other aquatic organisms moving between the Yakima River and Swamp Lake. Specifically, connectivity is important here because there are several important breeding areas for amphibians on both sides of I-90, at Swamp Lake, and at ponds along the Yakima River. The current culverts are passage barriers to juvenile fish.

- Improve water quality parameters in the Swamp Creek CEA because I-90 passes closest to the Yakima River/Swamp Creek wetlands at this location. Improvements include reducing maximum summer water temperatures and controlling non-point source discharges of stormwater and sediment into waterways from the roadway and maintenance facility. This objective is linked...
to riparian vegetation management, conservation of groundwater and restoration of natural flow paths, and wetland protection and enhancement.

- Restore natural channel, floodplain, and wetland flow paths at the Swamp Creek crossing structure.
- Restore natural surface and subsurface flow paths connecting the extensive wetland complex west of Swamp Creek to wetlands and aquifers on the Yakima River floodplain.
- Restore natural surface and subsurface flow paths connecting pockets of wetlands upslope of the Stampede Pass interchange to wetlands and aquifers on the Yakima River floodplain.

What design options did we evaluate at Swamp Creek?

Exhibit 3.9-3 shows the various options designed for Swamp Creek. The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment. Culvert dimensions are approximate. They will be sized to meet WDFW stream simulation requirements for fish passage.

**Option A**

Option A would construct twin multi-span bridges (approximately 240 feet long) over Swamp Creek that would provide a vertical clearance ranging from 10 feet to 16 feet. The I-90 profile would be raised, and the Stampede Pass interchange would be reconstructed to an overcrossing. Twin bridges (approximately 120 feet long) would be constructed at the east end of the interchange with an approximate vertical clearance of 12 feet to 13 feet. Bridge spans would be approximately 84 feet in width to accommodate interchange ramps (compared to 60-foot widths for structures over 3 lanes with shoulders). Four HCZs were identified for this option (Exhibit 3.9-3a).

**Option B**

Option B would construct three sets of twin bridges, each approximately 120 feet long, at various crossing locations in the CEA. The twin bridges at the west end of the Stampede Pass interchange would have a vertical clearance of about 16 feet, while those at the Swamp Creek crossing would have a vertical clearance ranging from 9 feet to 16 feet. The structures at the east end of the interchange would provide vertical clearance ranging from 15 feet to 17 feet. The twin 120-foot bridges to the east would be about 84 feet wide in each direction to accommodate additional width due to interchange ramps. The highway profile would be raised up to 14 feet to provide for additional clearance at the crossing structures, and the existing undercrossing structure for Stampede Pass Road
would be replaced. In total, five HCZs have been identified in this option (Exhibit 3.9-3b).

Option C

Option C would construct twin bridges at Swamp Creek, about 120 feet long with an approximate vertical clearance ranging from 8 feet to 17 feet. The HCZ at the east end of the interchange would include a bottomless culvert approximately 16 feet wide by 10 feet high. The highway profile would be raised as high as 18 feet in places to provide optimal clearance at the crossing structures and the existing undercrossing structure for Stampede Pass Road would be replaced. In total, six HCZs have been identified in this option (Exhibit 3.9-3c).

How will the options perform?

The Swamp Creek CEA contains extensive wetlands associated with Swamp Creek, Swamp Lake, Bonnie Creek, and the Yakima River floodplain. These wetlands support a diverse variety of species and serve as breeding areas for amphibian populations. Two special soil types are also present in the CEA. Topography, high rates of ungulate roadkill, and sighting records, including sightings of rare large carnivores, suggest that larger high-mobility species would be expected to move through this CEA. Consequently, our objectives for wildlife
connectivity at this CEA call for year-round linkage for both high- and low-mobility species.

This is also an area of complex subsurface and surface flows that interact with alluvial aquifers and wetlands in the Yakima River floodplain. At I-90, Swamp Creek is naturally confined within a channel that cuts through glacial deposits before transitioning onto the Yakima River floodplain.

To fully support the development of successful designs, groundwater monitoring and modeling will be needed to understand two- and three-dimensional flow patterns in this area for use in refining the designs and locations of HCZs. Additional geomorphic analysis of Swamp Creek will be needed to design a naturally stable channel configuration beneath the bridges that would tie into stream reaches upstream and downstream of the highway.

**Option A**

Option A would meet wildlife connectivity objectives, assuming the crossing structure at the east end of the interchange has a minimum clearance of 16 feet. Although the extended width of the bridges over Swamp Creek would reduce openness, the approximate clearance of 16 feet under this structure should be sufficient to provide year-round crossing performance for both high- and low-mobility species, except possibly during the highest snowpack years. Placement of an HCZ at the west end of the interchange in place of a crossing structure diminishes permeability relative to Option B. The need for increasing the clearance at the east end bridge is based in part on concern that human activities (private inholding and the WSDOT maintenance facility near Swamp Creek) would negatively affect performance of the crossing structure at Swamp Creek.

Option A meets hydrologic connectivity objectives. The bridges over Swamp Creek would provide sufficient floodplain width to restore natural channel processes, fish passage, and sediment transport. HCZs near Swamp Creek and at the Stampede Pass interchange would restore flow paths between upslope wetlands and alluvial aquifers and wetlands on the Yakima River floodplain.

The reconfiguration of the Stampede Pass interchange under Option A poses some challenges for maintaining hydrologic connectivity. If not carefully designed, the new westbound off-ramps could enlarge cut slopes, which would intercept surface and subsurface flow within the HCZ on the east side of the interchange. The current design minimizes these impacts by raising the profile of the highway and off-ramps in this area. This minimizes new cut slopes to only the westernmost 50 to 100 feet of the HCZ, with a maximum depth of cut of less than 6 feet. The raised profile also minimizes changes in the slopes and elevations of drainage features along the north side of the off-ramp, allowing for improved attenuation and dispersion of stormwater and snowmelt runoff.
Option B

Option B meets wildlife connectivity objectives. In Option B, crossing structures with attributes suitable for both high- and low-mobility species are distributed across the CEA, linking the diverse habitats within this CEA and providing habitat restoration opportunities. Relative to Option A, Option B has both positive and negative features.

On the positive side, Option B provides a crossing structure to the west of the privately owned parcel, reducing the potential effects of human activity on this crossing structure’s performance. The crossing structure to the west, which replaces an HCZ in Option A, also provides better habitat connections for wetlands and nearby mature forest. In addition, the crossing structure to the east end of the interchange provides higher clearance than Option A, based on current preliminary designs. High clearance is especially important for this structure because the interchange ramps increase the passage length of the crossing structure, reducing crossing structure openness.

On the negative side, all crossing structures in Option B are 120-foot-long bridges, which provide less openness than the 240-foot-long bridge over Swamp Creek in Option A.

For balance, we find that Option B is more likely to fulfill wildlife connectivity objectives at this CEA because it provides better habitat linkages and better separation from a potential source of human disturbance.

Option B meets hydrologic connectivity objectives. The bridges over Swamp Creek would provide sufficient floodplain width to restore natural channel processes, fish passage, and sediment transport. Vertical abutments should be used to maximize floodplain and wetland width beneath the bridge. Bridges and HCZs near Swamp Creek and at the Stampede Pass interchange would restore flow paths between upslope wetlands and alluvial aquifers and wetlands on the Yakima River floodplain.

Option C

Option C does not meet wildlife connectivity objectives. In addition to the height issues described for Option B, Option C places the only functional crossing for high-mobility species in a location that is most susceptible to disturbance from human activities.

This option meets hydrologic connectivity objectives, with hydrologic benefits similar to Option B. Option C uses an HCZ west of Swamp Creek in place of the bridge in Option B, and therefore provides less continuous wetland flow through the highway right of way.

The bridge in Option C provides sufficient floodplain width to restore natural channel process, fish passage, and sediment transport.
Exhibit 3.9-4 at the end of this section provides a detailed comparison of the options for this CEA.

**Performance Standards**

All performance standards apply to the Swamp Creek CEA (see Attachment 3).

**Are there other potential restoration opportunities at Swamp Creek?**

- Relocate or close the Crystal Springs Campground, and relocate Forest Service Road 5400 (see Bonnie Creek CEA section for details).

- Remove fill from the stockpile and log yard area just north of the interchange. This fill is in an area that appears historically to have been a wetland. Restoration of this wetland could be a form of in-kind, onsite mitigation (Pierce 2005). This wetland may have been connected to wetlands currently designated as TW, SW, RW, and HE south of I-90. If Wetland HE is hydrologically linked to the Yakima River, restoration of the filled wetland and reconnection of wetlands north of I-90 to Wetland HE would be appropriate (Pierce 2005).

- Eliminate the Stampede Pass interchange.
  - This interchange constrains improvements in hydrologic and ecological connectivity at the Swamp Creek CEA. If the interchange was eliminated, I-90 could be elevated in this area.
  
  - Removal of this interchange would also require realignment of access roads from the Cabin Creek interchange to link up with the Kachess Lake and Stampede Pass roads. These realignments would have impacts on ecological connectivity. Further study would be necessary to evaluate the balance between beneficial effects from interchange removal and negative effects of access road realignments.

- Remove the barrier dam upstream of I-90 (in cooperation with the private landowner) (WSDOT 2002b) to improve fish passage in Swamp Creek and to reach full restoration potential of the Swamp Creek channel and floodplain.
### Swamp Creek Options Comparison Table

**Exhibit 3.9-4**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s multiple structures would take advantage of topographic opportunities.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>This option’s locations are similar to the other options, but the smaller structures would not take full advantage of the broad topographic corridor; this option would be less permeable than other options.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s location closer to wetlands would be less buffered by native vegetation than forested areas.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Bridges to the west would move crossings away from areas of higher human use. As in Option A, this option’s location closer to wetlands would be less buffered by native vegetation than forested areas.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>Yes</td>
<td>Western bridge would meet minimum height clearance. We recommend raising the minimum bridge height to 16 feet on the eastern bridge.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>All bridges would meet minimum height clearance of 16 feet.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Minimum clearance height is too low for year-round use by high-mobility species; no bridges on east and west ends of Swamp Creek.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>Yes</td>
<td>There is a special soil type in this CEA (K254-Kachess gravelly sandy loam; K329); this soil is present at the Swamp Creek bridge. Under this option, lighting may be sufficient to support plant development because of the height (16-foot minimum clearance at the west end and Swamp Creek bridge), the 240-foot length that expands lighted horizon, and split lanes. We recommend raising the minimum bridge height to 16 feet on the eastern bridge. More native vegetation would be linked to better diversity overall; the crossing structure would more closely mimic natural habitat diversity.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The minimum bridge clearance of 16 feet would be met on all bridges. This option would link less wetland but would provide greater linkage for high-mobility species in a location farther from human disturbance. The eastern bridge would connect special soil types and species in this CEA.</td>
</tr>
</tbody>
</table>
## Swamp Creek Options Comparison Table

### Exhibit 3.9-4

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
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</tr>
</thead>
<tbody>
<tr>
<td>C No</td>
<td>This option does not connect wetland habitat like Options A and B. This option does not connect a special soil type and species, and the low vertical clearance would restrict habitat under the structure.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Yes</td>
<td>The Swamp Creek bridge would connect aquatic, terrestrial, and wetland habitats. The east bridge would connect soils.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B Yes</td>
<td>Three bridges connect the majority of habitats.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C No</td>
<td>Wetlands are not connected. Soils are not connected. This option lacks high-mobility species connection to the east.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Are populations of species associated with different habitat types in this CEA connected?

| A Yes | Swamp Creek bridge has significant disturbance, including the frontage road, maintenance facility, and private development. |
| B Yes | West and east bridges are away from human activities; Swamp Creek bridge is in area of most human activity. Closure of Crystal Springs Campground would increase the effectiveness of crossing structures. |
| C No | Swamp Creek bridge has significant disturbance, including the frontage road, maintenance facility, and private development. The only functional crossing structure provided in Option C is located within the area of the greatest human use. |

### Can human activities in this CEA be managed for compatibility with the function of the crossing structures?

| A Yes | With some small private holdings. |
| B Yes | Same as Option A. |
| C Yes | Same as Option A. |

### Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?

| A Yes | The bridge would restore natural aquatic habitat and channel functions in Swamp Creek, and would remove a partial fish passage barrier at I-90. |
| B Yes | The bridge would restore natural aquatic habitat and channel functions in Swamp Creek and would remove a partial fish passage barrier at I-90. Further analysis is needed to determine if the 120-foot span limits ability to meet riparian reserve standards for natural riparian vegetation. |
| C Yes | The bridge would restore natural aquatic habitat and channel functions in Swamp Creek and remove a partial fish passage barrier at I-90. Further analysis is needed to determine if the 120-foot span limits ability to meet riparian reserve standards for natural riparian vegetation. |
### Swamp Creek Options Comparison Table
Exhibit 3.9-4

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>A</td>
<td>Yes</td>
<td>The bridge would allow the channel to meander as it transitions onto the Yakima River floodplain. This system was once more dynamic as the Yakima River shifted up into the lower Swamp Creek. Current dam operations and downstream roads now limit this potential. This option therefore provides sufficient channel migration for current conditions, even though it does not fully restore the historic channel migration zone.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The bridge would allow the channel to meander as it transitions onto the Yakima River floodplain but to a lesser extent than Option A. This system was once more dynamic as the Yakima River shifted up into the lower Swamp Creek. Current dam operations and downstream roads now limit this potential. This option therefore provides sufficient channel migration for current conditions, even though it does not fully restore the historic channel migration zone.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>The bridge would allow the channel to meander as it transitions onto the Yakima River floodplain but to a lesser extent than Option A. This system was once more dynamic as the Yakima River shifted up into the lower Swamp Creek. Current dam operations and downstream roads now limit this potential. This option therefore provides sufficient channel migration for current conditions, even though it does not fully restore the historic channel migration zone.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydorperiods?</td>
<td>A</td>
<td>Yes</td>
<td>The raised highway profile minimizes new cut slopes and flow interception along the westbound off-ramps, and therefore avoids lowering water levels and disrupting hydorperiods of upslope wetlands.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>To avoid hydorperiod impacts, HCZ designs and locations should be refined based on groundwater monitoring and investigation of subsurface flow paths.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>To avoid hydorperiod impacts, HCZ designs and locations should be refined based on groundwater monitoring and investigation of subsurface flow paths.</td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>Yes</td>
<td>Bridge at Swamp Creek would restore continuous wetland flow under 240 feet of highway on the Swamp Creek floodplain.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Bridge at Swamp Creek would restore continuous wetland flow under 120 feet of highway on the Swamp Creek floodplain. Bridge west of Swamp Creek would restore 120 feet of continuous wetland flow in a 500-foot-long HCZ that links high value wetlands to the Yakima River floodplain.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Bridge at Swamp Creek would restore continuous wetland flow under 120 feet of highway on the Swamp Creek floodplain.</td>
</tr>
</tbody>
</table>
## Swamp Creek Options Comparison Table

### Exhibit 3.9-4

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>The Swamp Creek bridge would restore flow paths on the Swamp Creek floodplain. HCZs east of Swamp Creek and near the Stampede Pass interchange would restore wetland and subsurface flow paths to the Yakima River floodplain. The raised highway profile at the Stampede Pass interchange minimizes the depth and length of new cut slopes along the westbound off-ramps, and therefore minimizes new interception of surface and subsurface flow along the north side of the highway.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The Swamp Creek bridge would restore flow paths on the Swamp Creek floodplain. Bridges and HCZs east of Swamp Creek and near the Stampede Pass interchange restore wetland and subsurface flow paths to the Yakima River floodplain.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>The Swamp Creek bridge would restore flow paths on the Swamp Creek floodplain. HCZs east of Swamp Creek and near the Stampede Pass interchange restore wetland and subsurface flow paths to the Yakima River floodplain.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove existing highway fill from 240 feet of the Swamp Creek floodplain.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option would remove existing highway fill from 120 feet of the Swamp Creek floodplain. Vertical abutments should be used to maximize floodplain and wetland width beneath the bridge.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>This option would remove existing highway fill from 120 feet of the Swamp Creek floodplain. Vertical abutments should be used to maximize floodplain and wetland width beneath the bridge.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove compacted fill from 240 feet of historical floodplain and wetlands at Swamp Creek. Bridge east of the Stampede Pass interchange would remove 100 feet of compacted fill from a seepage zone.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option would remove compacted fill from 120 feet of historical floodplain and wetlands at Swamp Creek. Bridge east of the Stampede Pass interchange would remove 100 feet of compacted fill from a seepage zone. Bridge west of Swamp Creek would remove compacted fill from 120 feet of wetlands.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>This option would remove compacted fill from 120 feet of historical floodplain and wetlands at Swamp Creek.</td>
</tr>
</tbody>
</table>
3.10 Toll Creek CEA

What are the conditions at Toll Creek?

The Toll Creek CEA (Exhibit 3.10-1) is located between MP 63.5 and MP 64.2. This area includes two stream crossings—Toll Creek on the east side of the Cabin Creek interchange and an unnamed creek on the west side of the interchange. Although many areas near Toll Creek have been disturbed by logging activities, the Toll Creek area has not experienced much disturbance. Toll Creek flows beneath I-90 in a culvert with a 4-foot-wide oval inlet and a 24-inch-diameter concrete outlet.

An unnamed creek enters the highway prism in a 3-foot-diameter culvert inlet and discharges out of an 8-foot by 10-foot concrete box culvert with a 2-foot vertical drop at the outlet apron. On this outlet end, the creek meanders through about a 100-foot-wide valley with mild side slopes. About 200 feet downstream of the outlet, the creek disperses into a wetland which extends across the broadening valley.

Vegetation Community

The important habitats in the Toll Creek CEA include Toll Creek, riparian, wetland, and mature/old growth forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western
redcedar, western white pine, and red alder. This CEA links contiguous blocks of old growth on both sides of I-90. In Toll Creek, the dominant tree species include Douglas-fir in upland areas, with western redcedar along riparian and wetland edges. The area contains some mountain hemlock south of I-90. Black cottonwood is found sporadically in wetter areas, along with some lodgepole pine. Understory vegetation includes vine maple, spirea, Oregon boxwood, and hazelnut. The Toll Creek CEA provides the opportunity to link high quality old growth forest, riparian, stream, and wetland habitats and the species associated with these habitats on both sides of I-90.

**Wildlife/Terrestrial Species Linkages**

The Toll Creek CEA has the potential to provide important linkage for species associated with old growth. These species are of concern throughout the Washington Cascades (USDA Forest Service 1994). Species associated with old growth include Pacific fisher, northern flying squirrel, northern spotted owl, marbled murrelet, and a diversity of rare and unique bryophytes, lichens, fungi, and vascular plants. This CEA also has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, lizards, salamanders, and terrestrial mollusks, as well as many rare species such as wolverine, lynx, and gray wolf.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2.

Late successional habitat, which is an important component of species diversity, is located on both sides of I-90 in the Toll Creek CEA, along with a soil type that is important to low-mobility species, K254 (Kachess gravelly sandy loam). The area along I-90 between the Stampede Pass and Cabin Creek interchanges is a particularly important location for wildlife connectivity. This area consists of both relatively flat terrain and a bedrock ravine, with wetland/riparian habitats throughout. Prior to construction of I-90, an unnamed creek flowed through a 30- to 50-foot-wide ravine west of the Cabin Creek on-ramp. This area was a riparian corridor through which animals would have naturally been funneled. A complex of wetlands and small channels historically occupied the bottom of this ravine. The I-90 roadbed filled in most of this habitat within the highway right-of-way, and confined wetland flow into a single culvert, resulting in the loss of the wildlife travel corridor.

Singleton and Lehmkuhl (2000) recorded the presence of a cluster of three bobcat and five coyote crossings in the area between the Stampede Pass and Cabin Creek exits (MP 63.3 to MP 63.7) during two winters of snowtracking. Species detected from automatic camera stations and snowtrack surveys in the general area include mule deer, elk, black bear, bobcat, coyote, red fox, Douglas squirrel, northern flying squirrel, and snowshoe hare.
The road density in the Toll Creek subwatershed is 3.8 miles of road per square mile. USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The Toll Creek area currently has low recreational use. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

**Stream Channel Function**

Toll Creek has a small watershed area of approximately 419 acres. It flows down the west flank of Amabilis Mountain. The upper portion of the creek has eroded into colluvium that overlies Naches Formation rocks. At I-90, the creek forms an alluvial fan as it transitions onto a glacial terrace. Toll Creek historically migrated across the alluvial fan and is now confined at the highway by a culvert. The crossing has been relocated to the west at a point where the structure could serve both the creek and a depressional wetland area. The creek now discharges sediment and debris into the wetland before crossing under the highway.

Toll Creek parallels Forest Service Road 4823 for approximately 300 feet downstream from I-90 before passing beneath 4823, entering a mature forest enroute to the Yakima River. Concentrated flood-flow discharges from Toll Creek frequently (5-year recurrence interval) scour the road fill material from Forest Service Roads 4823 and 4823-127, contributing sediment to the Yakima River. The I-90 culvert is a complete barrier to fish passage to its length, water depth, and flow regime.

Toll Creek is an intermittent stream because of its small watershed. During summer investigations, surface flow ceased a few hundred feet upstream of I-90, reappeared at the end of the I-90 culvert, and disappeared again at Forest Service Road 4823 (WSDOT 2002b).

West of the Cabin Creek interchange, an unnamed creek drains a series of wetlands in a broad ravine. This unconfined perennial stream is less than 3 feet wide, with a gradient less than 1 percent. The floodplain width and channel migration zone is 60 to 75 feet wide. Highway fill material and culvert width currently constrict flow under I-90. A May 25, 2005, field inspection found orange iron oxide precipitate covering the creek substrate, suggesting a surface discharge of groundwater flowing under I-90 (Martin 2005). Streamflow is supported by both surface runoff and shallow groundwater discharge from wetlands.

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1 Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
**Wetlands**

The Toll Creek CEA has Category I wetlands along the north side of the I-90 and small Category II wetlands west of the Cabin Creek interchange along the south side of the highway. These wetlands have been disconnected to the north and south by I-90, and to the west by roadfill.

The wetland associated with the unnamed creek to the west of the Cabin Creek interchange was partially logged within the past 20 years and does not show signs of returning to a natural condition. Bog development includes a buildup of organic matter over centuries which, when disturbed, can produce conditions that are detrimental to tree growth. Regeneration of this area is likely to be slow and take hundreds of years to develop a forested system. The area probably provides some important functions within the watershed, including nutrient export and flood storage during snow melt events. This wetland was classified as a Category I wetland based on mature forest stands along the edges.

**Water Quality**

Except for a few isolated measurements, no temperature data for Toll Creek exist. The maximum temperature observed during surveys was 52°F in July 2001 (TetraTech 2002). The creek is very well shaded above I-90, and the water quality and temperature were exceptional, hence temperature would not be limiting factor for the presence of fish.

The MDT rated water quality in Toll Creek as not properly functioning downstream of I-90. Specific contributing factors include fine sediment (traction sand from the highway), the presence of metals in stormwater runoff, and temperature.

**Fish Species and Aquatic Habitat Linkages**

In 2001, Jones & Stokes surveyed habitat conditions along 1,175 feet of Toll Creek (from 255 feet downstream of I-90 to 920 feet upstream of I-90). In this reach, the wetted width is 2.1 to 9.6 feet wide, with an average of 4.5 feet. The stream gradient ranges from 0 to 16 percent, with an average of 5.2 percent. Pool frequency in Toll Creek is high at 80.9 per mile.

Because of the lack of disturbance in the upper watershed, isolated fish may be present. Based on observations of the stream channel characteristics and flow regime, Toll Creek downstream of I-90 was deemed to be nonfish bearing (WSDOT 2002b). The unnamed stream was not surveyed.

Large woody debris is abundant in Toll Creek above I-90. As a result, habitat complexity is high. Below I-90, conditions are less favorable due to I-90 and Forest Service Road 4823; however, the creek does merge into the Yakima River and its floodplain, which provides good riparian vegetation.

Near I-90, the dominant substrate in Toll Creek is fine sediments; above I-90, the dominant substrate is gravel and cobble. The fines near I-90 can be attributed to
road runoff and traction sand. Substrate was embedded by fines only where the channel was adjacent to I-90.

The MDT determined that Toll Creek area’s aquatic habitat is at risk from fine sediment from the highway. The stream channel is disconnected from its floodplain, resulting in loss of recharge, and is artificially confined. Fill from the highway has affected groundwater flow west of I-90. The highway, as well as seasonal low water flow below I-90, create barriers to fish passage. Drainage from Amabalis Mountain has caused slope instability in the area.

What are the objectives at Toll Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the Pacific silver fir/western hemlock species assemblage zone. Year-round connectivity would require high structures due to winter snowpack (12-foot clearance plus 4-foot average snowpack, for a total minimum clearance of 16 feet). High structures would provide light under the structures to support plant life and increase the openness of the structure.

- Build structures to provide connectivity for at least 36 species of mammals, 10 species of amphibians, and 21 species of mollusks documented or suspected to occur in the area (see list in Attachment 2).

- Connect special soil type (K254) and the associated low-mobility species.

- Provide passage for fish and other aquatic organisms moving throughout the stream system.

- Restore historical channel alignment of Toll Creek upstream of I-90.

- Restore natural movement of sediment, debris, and water through the Toll Creek crossing structure.

- Remove fill and restore wetland flow through the I-90 roadbed at the unnamed creek west of the Cabin Creek interchange.
What design options did we evaluate at Toll Creek?

Exhibit 3.10-2 shows the options designed for Toll Creek. The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment. Culvert dimensions are approximate. They will be sized to meet WDFW stream simulation requirements for fish passage.

Options A and B

Options A and B offer identical crossing structures in the CEA (Exhibit 3.10-2a). The first structure is a set of twin bridges (approximately 120 feet long with vertical clearance ranging from 14 feet to 16 feet) that would be constructed west of the Cabin Creek interchange at an unnamed creek. A second structure would be installed at Toll Creek. This structure, a culvert approximately 6 feet wide and 5 feet high, would follow as closely as feasible the historic creek alignment. This culvert would be about 225 feet in length, crossing under all traffic lanes and shoulders in both directions, without an opening in the median.

Option C

This option would install a bottomless culvert approximately 16 feet wide with vertical clearance of 12 feet at the unnamed creek west of the Cabin Creek interchange (Exhibit 3.10-2b). At Toll Creek, the same 6-foot by 5-foot-long culvert described in Options A and B would be installed.

Performance Standards

All performance standards apply to the Toll Creek CEA (see Attachment 3).

How will the options perform?

The Toll Creek CEA aligns with wildlife corridors identified in previous studies and is important for high-mobility species. Toll Creek is on the southeastern edge of the valley between Keechelus Ridge and Amabilis Mountain. Consequently, wildlife connectivity objectives for this CEA are similar to those for the other CEAs in this valley (Price and Noble, Bonnie, and Swamp creeks). Providing effective wildlife connectivity at Toll Creek is important because of the relatively long distance to the next large crossing structure to the east (Hudson Creek, about 3 miles away), and because of questions about the effectiveness of the Swamp Creek CEA options, which is the next CEA to the west.
The crossing at the unnamed creek to the west of Toll Creek offers the best opportunity to build an effective crossing structure in this CEA because of favorable terrain at this location. Consequently, our evaluation of how ecological connectivity objectives are met at this CEA focuses on the proposed structure at the unnamed creek. From a hydrologic connectivity perspective, the Toll Creek crossing should be designed to restore water and debris conveyance along the historical channel alignment.

**Options A and B**

Options A and B (which are the same) would provide for the overall wildlife connectivity objectives at this location. The crossing structure at the unnamed creek has the size and clearance attributes needed to provide for year-round connectivity of terrestrial species and to adequately link habitats in the CEA. The culvert at Toll Creek may provide some crossing opportunities for terrestrial species, limited to seasons when some part of the culvert is dry and to smaller species that would use more confined structures.

Options A and B meet the hydrologic connectivity objectives for this CEA, and have equivalent hydrologic features. The Toll Creek structure would convey debris and reduce the amount of sediment and debris that is now discharged into a wetland at the existing culvert inlet. The twin 120-foot bridges would restore wetlands and floodplain flow paths through the roadbed at the unnamed creek west of the Cabin Creek interchange. Vertical abutments should be used to maximize floodplain and wetland width beneath the bridge.

**Option C**

Option C does not meet wildlife connectivity objectives. Constructing large bottomless culverts at the unnamed creek could allow crossing by many species and would meet our minimum height performance standard. Constructing large bottomless culverts at the unnamed creek could allow crossing by many medium-size species; however, it would not meet our minimum standards for large high-mobility species. The narrow width (16 feet) and 75-foot length of these culverts at the unnamed creek reduce openness and space available for placement of habitat-enhancing features within the structure, making this option less likely to be functional for all species during all seasons. This structure also would not link both wetland and upland habitats found in this CEA.

This option does not meet hydrologic connectivity objectives because it would not restore wetland and floodplain flow paths at the unnamed creek west of the Cabin Creek interchange. The creek would be confined within a culvert that would restore only 16 out of a potential 120 feet of floodplain width.

See Exhibit 3.10-3 at the end of this section for a detailed comparison of this CEA’s options.
Are there other potential restoration opportunities?

- Restore the stream channel downstream of I-90, including improving connections between the channel and its floodplain, and restoring the gradient to reduce channel head cutting and instability.

- Restore Wetland QW north of I-90.

- Modify the size and location of the Cabin Creek Sno-park along Forest Service Road 4823-000 to restore a portion of Toll Creek’s floodplain by removing the berm and restoring riparian vegetation on the floodplain between the parking area and Toll Creek. The objective would be to:
  - Allow for overbank flooding and shallow groundwater recharge.
  - Improve energy dissipation and sediment filtration on Toll Creek’s floodplain.
  - Improve water quality by eliminating or slowing runoff and sediment from parking area.

- Increase the culvert size at Toll Creek’s crossing of Forest Service Roads 4823-000 and 4823-127 to eliminate in-channel streambank erosion and road-related fill erosion during storm runoff events.
## Toll Creek Options Comparison Table

**Exhibit 3.10-3**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>The crossing of the unnamed creek would link with the high permeability area identified by Singleton and Lehmkuhl (2000).</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>Yes</td>
<td>The clearance and openness of the structure over the unnamed creek would accommodate high-mobility species.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>The clearance of the unnamed creek’s culvert would be adequate, but overall openness would be unlikely to provide adequate performance.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>Yes</td>
<td>There is a special hydric soil type (K254) on both sides of highway that can be linked with a high clearance structure. High clearance may also permit plant growth within the structure.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option’s culvert would provide little opportunity to place stumpwalls or other materials to diversify microhabitat within the crossing structure. Structure, which would be about 225 feet long, would present a long expanse of unsuitable habitat for many low-mobility species.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>Yes</td>
<td>The crossing structure over the unnamed creek would span higher quality wetland and some terrestrial habitat.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option’s culvert would not link high-mobility species associated with wetland and terrestrial species.</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>There is disturbance to the south from roads and recreation (Cabin Creek Sno-park).</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>
## Toll Creek Options Comparison Table
### Exhibit 3.10-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td>Nearly all land is public in vicinity of project.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>

### Hydrologic Connectivity

| Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats? | A      | Yes            | Yes, assuming that during design the culvert is properly sized for debris passage. Because of the large debris flow events that occasionally occur in this system, this culvert may have to be larger than the 6 foot by 5 foot box shown on plan drawings. An enlarged bottomless culvert would also provide better opportunities for channel restoration that the USFS could implement at the downslope Forest Service Road and Sno-park. The bridge at the unnamed creek would fully restore natural channel functions in this low gradient wetland system. |
|                                                                                                                                       | B      | Yes            | Same as Option A. |
|                                                                                                                                       | C      | Yes            | Yes, assuming that during design the culvert is properly sized for debris passage. Because of the large debris flow events that occasionally occur in this system, this culvert may have to be larger than the 6-foot by 5-foot box shown on plan drawings. An enlarged bottomless culvert would also provide better opportunities for channel restoration that the USFS could implement at the downslope Forest Service Road and Sno-park. The culvert at the unnamed creek would restore movement of aquatic organisms, wood, sediment, and debris, but would limit restoration of riparian functions. |

| Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans? | A      | Yes/No | Yes, for unnamed creek. The bridge would restore opportunity for channel sinuosity under 120 feet of highway. No, for Toll Creek. The single culvert would confine Toll Creek to one channel. However, downslope roads and land uses would severely limit opportunities for restoration of natural channel migration. |
|                                                                                               | B      | Yes/No | Same as Option A. |
|                                                                                               | C      | Yes/No | Yes, for unnamed creek. The 16-foot bottomless culvert would provide adequate room for channel migration. No, for Toll Creek (same as Option A). |

| Does this option avoid impacts on wetland hydroperiods? | A      | Yes | Yes, assuming elevations under the bridge are graded to tie into existing wetland elevations above and below the highway. |
|                                                        | B      | Yes | Same as Option A. |
### Toll Creek Options Comparison Table

**Exhibit 3.10-3**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>C</td>
<td>Yes</td>
<td>Yes, assuming the inlet and outlet elevations in the culvert tie into existing wetland elevations on both sides of the highway, and the culvert bottom provides sufficient roughness to match natural flow depths and velocities.</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Yes</td>
<td>The bridge over the unnamed creek would restore continuous wetland flow connecting high value wetlands for 120 feet of highway.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Highway fill would only provide continuous flow for a 16-foot wide highway segment, blocking flow for the remaining ±100 feet of potential wetland flow width.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes/No</td>
<td>Yes, on the unnamed creek. The bridge would restore wetland and subsurface flow under 120 feet of highway. No, at Toll Creek. The culvert would intercept and channelize subsurface flow that is associated with Toll Creek debris deposits.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes/No</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>The bottomless culvert would confine surface flow to a 16-foot width in the unnamed creek and its associated wetlands. The culvert at Toll Creek would intercept and channelize subsurface flow that is associated with Toll Creek debris deposits.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s bridge would remove fill from the unnamed creek floodplain under 120 feet of highway. Vertical abutments should be used to maximize floodplain and wetland width beneath the bridge.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>The bottomless culvert would only remove fill from a 16-foot highway segment, out of about 120 feet of potential floodplain width.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s bridge would remove fill from most of the floodplain and wetland soils at the unnamed creek (under 120 feet of highway).</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option’s bottomless culvert would only remove fill from a 16-foot highway segment, out of about 120 feet of potential wetland and floodplain width.</td>
</tr>
</tbody>
</table>
3.11 Cedar Creek CEA

What are the conditions at Cedar Creek?

The Cedar Creek CEA (Exhibit 3.11-1) is located between MP 64.5 and MP 64.7. Cedar Creek is a steep, confined stream flowing off Amabilis Mountain. It crosses under I-90 in a 4-foot box culvert and under Forest Service Road 4823 in a culvert. Downstream of Forest Service Road 4823, the creek passes through a power line corridor before connecting into a network of wetlands, ponds, and channels within the Yakima River floodplain.

Vegetation Community

The important habitats in the Cedar Creek CEA include Cedar Creek and riparian, wetland, and mature forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. The Cedar Creek CEA provides the opportunity to link mature forest, riparian, stream, and wetland habitat and the species associated with these habitats on both sides of I-90.
Wildlife and Terrestrial Species Linkages

The Cedar Creek CEA has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, lizards, salamanders, and terrestrial mollusks, as well as many rare species such as fisher, wolverine, lynx, and gray wolf.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2.

Wolverine tracks were documented on Amabalis Mountain approximately 1 mile north of I-90 in March 1998. Species detected from automatic camera stations and snowtrack surveys in this general area include mule deer, elk, bobcat, coyote, Douglas squirrel, northern flying squirrel, and snowshoe hare. Amphibian species found at this location were limited to tailed frogs.

Mollusks found during surveys (WSDOT 2002b) include Ancotrema sportella, Haplotrema vancourversense, Euconulus fulvus, Propysaon vanattae, and Vertigo columbiana.

The dominant soil in the Cedar Creek CEA is K347 Gilpar sandy loam. This soil type is associated with the following rare and/or commercially important fungi species—Boletus mirabilis, Gyromitra californica, Morchella angusticeps, Ramaria rasilispora (USFS 1994; USFS 2003).

The road density in the Cedar Creek subwatershed is 5.6 miles of road per square mile. USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The Cedar Creek CEA currently has low recreational use. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

Stream Channel Function

Cedar Creek flows down the west flank of Amabilis Mountain and is underlain by Naches Formation rocks. Upstream of I-90, the creek is naturally confined within colluvial deposits. At I-90, the creek transitions onto an alluvial terrace before entering the Yakima River. The creek historically developed an alluvial fan at this transition, with multiple channels and subsurface flow paths. The highway confined the creek within a culvert, blocking natural flow paths and causing the creek to incise downstream of the highway.

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1 Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
Cedar Creek has a watershed area of approximately 346 acres. The headwaters of the creek have been significantly altered due to timber harvest. Cedar Creek is a steep confined stream flowing off Amabalis Mountain, with limited shade and habitat cover above I-90. At the base of the mountain and downstream of I-90, the creek currently transitions onto an alluvial fan. The culvert under I-90 is insufficient in size to accommodate this transition in stream type. Undersized culverts and artificial channel confinement contribute to hazards in passing sediment and wood from debris flows, a reduction in frequency of overbank flooding, reduced groundwater recharge, and accelerated in-channel erosion. Cedar Creek passes through a long culvert under I-90 that is a complete barrier to fish passage at all flows. Between I-90 and Forest Service Road 4823, Cedar Creek passes through a short section of young forest.

Some substrate embeddedness occurs in the reaches near I-90 due to influx of I-90 traction sand and bank material from eroding areas just downstream of the I-90 culvert. Below Forest Service Road 4823, the creek flows through a power line corridor and a complicated network of channels, wetlands, and ponds associated with the Yakima River floodplain. Although not surveyed, the substrate would be expected to be dominated by fines because of the disturbance of the power line corridor, the low gradient of the stream, and the numerous wetlands and ponds associated with the floodplain.

**Wetlands**

The Cedar Creek CEA contains several small streams that drain into the Yakima River. Several large wetland complexes are found on the southwest side of I-90 that would not be directly affected by the project. These wetland areas may currently receive some highway runoff from I-90 and would directly benefit from stormwater treatment facilities that are planned for the new roadway.

**Water Quality**

Except for a few isolated measurements, no temperature data for Cedar Creek exist. The maximum temperature measured during surveys was 59°F in July 2001. The creek is moderately well shaded below I-90, and temperature would probably not be a factor that limits the presence of fish. However, the creek is
intermittent during the summer, which would limit the length of stream that the fish would be able to access.

The MDT rated water quality in Cedar Creek as at risk due to fine sediment in runoff from I-90.

**Fish Species and Aquatic Habitat Linkages**

Aquatic condition surveys were conducted along 1,365 feet of Cedar Creek from Forest Service Road 4823 to 459 feet above the I-90 culvert. In this reach, the channel has been artificially confined to pass flow in a single channel beneath I-90 and Forest Service Road 4823 (WSDOT 2002b).

No fish were detected during aquatic surveys of Cedar Creek (WSDOT 2002b). Limiting factors for fish are intermittent stream flow, a complete barrier at the I-90 culvert, and a steep gradient above I-90.

During the summer, the creek dewateres south of I-90.

The amount of large woody debris in Cedar Creek is low, especially above Forest Service Road 4823. Below Forest Service Road 4823, Cedar Creek converges with the Yakima River through a complex network of channels, wetlands, and ponds within a forested wetland that makes up the Yakima River floodplain. Riparian vegetation is well developed here. As a result, habitat complexity is low upstream of Forest Service Road 4823, but high downstream. The creek passes through managed forests, some of which have been recently logged.

The MDT determined that Cedar Creek’s aquatic habitat was not properly functioning due to multiple barriers consisting of the culvert at I-90, Forest Service Road 4823, and the power line corridor. The stream channel lacks shade trees and is confined above I-90, but unconfined below. The I-90 crossing constricts flow capacity. Drainage from Amabilis Mountain has caused slope instability, logging and upslope roads have impacted the area, and the risk of debris flow from floods is high. Discussions with the USFS indicate that most of the debris is deposited on the highway and is not passed downstream onto the alluvial fan due to the undersized capacity of the culvert.
What are the objectives at Cedar Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the western hemlock/Pacific silver fir species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snowpack. High structures would provide light under the structures to support plant life and increase the openness of the structure.

- Build structures to provide connectivity for at least 35 species of mammals, 8 species of amphibians, and 14 species of mollusks documented or suspected to occur in the area (see list in Attachment 2). This is the only area where wolverine have been documented nearby.

- Provide passage for fish and other aquatic organisms moving throughout the stream system.

- Restore capacity for flow and debris passage at the Cedar Creek crossing.

- Provide a stream crossing structure that allows restoration of unconfined flow, channel processes, and shallow groundwater recharge on the terrace downslope of I-90.

What potential design options did we evaluate at Cedar Creek?

One design is under consideration at Cedar Creek (Exhibit 3.11-2). The design shown is conceptual and reflects current design at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Culvert dimensions are approximate. They will be sized to meet WDFW stream simulation requirements for fish passage.

Option A

Option A would install two culverts at Cedar Creek, one underneath the westbound lanes and the other beneath the eastbound lanes. They would be designed with a width that meets WDFW stream simulation requirements and provides for debris flow passage (Exhibit 3.11-2). Their height would be optimized to facilitate wildlife movement within the constraint of the road profile and to provide a natural substrate. Preliminary designs indicate that this CEA is likely to consist of a series of culverts, with the largest being at least 4 feet by 4 feet. One HCZ was identified to accommodate unconfined flow and groundwater recharge to wetlands south of the highway.

How will these options perform?

This CEA, located on the slopes of Amabilis Mountain, is the first of three CEAs that have challenges to providing effective ecological connectivity because of steep terrain. For the Amabalis Mountain CEAs (Cedar, Telephone, and Hudson
Creeks), constructability constraints have limited the development of design options capable of meeting connectivity objectives. Only the Hudson Creek CEA provides the opportunity to construct a crossing structure that meets the connectivity objectives for high-mobility species.

Objectives at this CEA include providing connectivity for high- and low-mobility species in the vicinity. Use of this area for wildlife movement could increase over time as adjacent habitats mature. The hydrologic connectivity objective is to restore channel processes, including providing capacity for flow and debris passage through the highway crossing.

The single design option for this CEA would not meet wildlife connectivity objectives. The proposed culvert array associated with the HCZ would provide crossing opportunities for small terrestrial species that are willing to use long, confined, crossing structures with limited openness. This use may be limited to seasons when some parts of the culverts are dry (not conveying surface flow). However, large, high-mobility species would not use these structures.

Hydrologic connectivity objectives would be met with an HCZ, which would restore natural channel processes by providing multiple crossing points for unconfined flow associated with Cedar Creek.
See Exhibit 3.11-3 for the details of our evaluation of the single design for this CEA.

**Performance Standards**

Site-specific performance standards that apply to this CEA will be determined at a later date (see Attachment 3).

**Are there other potential restoration opportunities?**

- Reduce road density in the Cedar Creek subwatershed to reduce the risk of debris flows and stream sedimentation, and improve habitat quality for terrestrial wildlife (in cooperation with USFS).

- Replant denuded areas in the upper watershed to reduce erosion of steep slopes (WSDOT 2002b).

- Restore riparian vegetation in the power line corridor to enhance stream shade, sediment filtering, bank stability, and organic nutrient inputs (in cooperation with entities transmitting electricity through the corridor). This would also enhance habitat continuity for wildlife species associated with riparian habitats and improve access to I-90 crossing structures.

- Improve the Forest Service Road 4823 crossing of both forks of Cedar Creek to improve hydrologic connectivity between the unconfined streamflow along the north side and the wetland complex along the south side of the road. Work would include a combination of elevating the road surface and increasing culvert capacity to pass unconfined surface flow and stormflow/snowmelt runoff through the road prism, without capturing and channeling runoff in the ditchline or on the road surface.
### Cedar Creek Option Comparison Table
#### Exhibit 3.11-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wildfire Connectivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>This CEA’s steep terrain and large clearcuts north of the highway currently limit habitat permeability.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>No</td>
<td>Minimum 4-foot by 4-foot culvert.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>No</td>
<td>No native soil or vegetation.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>No</td>
<td>This option would only link aquatic habitat.</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>Access to area north of highway is limited; access south of the highway limited by closed roads. Human use levels are low.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td>Vicinity is all publicly owned. Small privately owned parcel south of Telephone Creek.</td>
</tr>
<tr>
<td><strong>Hydrologic Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>A</td>
<td>Yes</td>
<td>Natural channel processes would be restored with an HCZ consisting of at least three culverts under eastbound lanes.</td>
</tr>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>A</td>
<td>Yes</td>
<td>An HCZ with at least three bottomless culvert crossings under eastbound lanes would provide for stream channel migration in response to debris deposition.</td>
</tr>
</tbody>
</table>
### Cedar Creek Option Comparison Table

#### Exhibit 3.11-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>This option would restore unconfined stream flow, allow for recharge of groundwater, and restore shallow subsurface flow paths in support of wetland hydroperiods.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>No</td>
<td>The roadbed would fill the Cedar Creek floodplain within the new right-of-way.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>No</td>
<td>The roadbed would fill the Cedar Creek floodplain within the new right-of-way.</td>
</tr>
</tbody>
</table>
3.12 Telephone Creek CEA

What are the conditions at Telephone Creek?

The Telephone Creek CEA (Exhibit 3.12-1) is located between MP 65.5 and MP 65.7. Telephone Creek’s drainage basin is 701 acres. The headwaters of Telephone Creek occur within a mature forest. Above I-90, the creek is steep, narrow, incised, and contains loose rock and wood debris. Between I-90 and Forest Service Road 4823, Telephone Creek interconnects with several large ponds. The creek drains into the Yakima River.

The creek has been affected by logging activities (including clear-cutting of adjacent areas) and construction of I-90, Forest Service Road 4823, and power line corridors. Telephone Creek passes through a 5-foot by 4-foot box culvert under I-90 that is a complete barrier to fish passage at all flows.

Vegetation Community

The important habitats in the Telephone Creek CEA include Telephone Creek and riparian, wetland, and mature forest. The forest habitat in the area is Western Hemlock Series, grading into Pacific Silver Fir Series at higher elevations in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. The Telephone Creek CEA provides the opportunity to link mature
forest, riparian, and wetland habitats and the species associated with these habitats on both sides of I-90.

**Wildlife and Terrestrial Species Linkages**

The Telephone Creek CEA has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, lizards, salamanders, and terrestrial mollusks, as well as many rare species such as fisher, wolverine, lynx, and gray wolf.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2.

Singleton and Lehmkuhl (2000) surveyed habitat conditions along 4,498 feet of Telephone Creek from Forest Service Road 4823 upstream to above I-90. In this reach, the channel width/depth ratio indicates a confined channel.

Species detected from automatic camera station and snowtrack surveys in this general area include mule deer, elk, bobcat, coyote, Douglas squirrel, northern flying squirrel, and snowshoe hare. Wolverine tracks were documented on Amabalis Mountain approximately 1 mile north of I-90 in March 1998.

Mollusks found during surveys (WSDOT 2002b) include *Ancotrema sportella* and *Haplotrema vancouverense*.

The dominant soil in the Telephone Creek area is K347 Gilpar sandy loam. This soil type is associated with the following rare and/or commercially important fungi species—*Boletus mirabilis*, *Gyromitra californica*, *Morchella angusticeps*, *Ramaria rasilispora* (USFS 1994; USFS 2003).

The road density in the Telephone Creek subwatershed is 3.8 miles of road per square mile.¹ USFS has committed to reducing road densities to less than

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¹ Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with
2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The Telephone Creek area currently has low recreational use. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

**Stream Channel Function**

Telephone Creek has a watershed area of approximately 701 acres. The upper reaches of the creek are naturally confined and cut through colluvium that overlies Naches Formation rocks on Amabalis Mountain. Landslides periodically send large debris flows down Telephone Creek, scouring upper reaches and depositing sediment in the lower reaches. At I-90, the creek transitions onto an alluvial terrace before entering the Yakima River. The creek historically developed an alluvial fan at this transition, with multiple channels and subsurface flow paths. Construction of I-90 covered the historic fan, and confined the creek within a single culvert.

Upstream from the project area, Telephone Creek is a steep, narrow, unstable channel typical of headwaters. The headwaters flow through a mature forest with a moderately open understory but dense overstory. The forest has been logged, but not for several decades. A clearcut area exists to the north of the mature forest, but it is far enough away that it does not influence Telephone Creek. The creek has incised, and the channel contains loose cobble, small boulders, and wood debris, suggesting a great deal of instability and erosion.

Substrate is predominantly gravel and cobble, but near the power line corridor, substrate is much finer. Substrate particle distribution measurements were taken (WSDOT 2002b) upstream and downstream of I-90. Both sites exhibited a low proportion of fine sediment, although the location below I-90 had a greater proportion of fines, which would be expected from road sanding activities on I-90. Substrate observations indicate that the area associated with the power line corridor had significant proportions of fines, which can be attributed to the power line corridor, nearby residential development, and associated dirt roads. Telephone Creek passes through the cleared power line corridor in a network of wetlands, channels, and ponds, which are features that facilitate the input and collection of fine sediments. In addition, one dirt road crossing within the power line corridor, another dirt road crossing further upstream had no culverts to pass the creek beneath the road, so Telephone Creek flows over the roads at those locations.

**Wetlands**

Telephone Creek meanders through a complicated forested wetland complex associated with the Yakima River floodplain. There are several large wetland...
complexes on the southwest side of I-90, but these would not be directly affected by the project. These wetland areas may currently receive some highway run-off from I-90 and would directly benefit from stormwater treatment facilities that are planned for the new roadway.

**Water Quality**

Summer water temperatures commonly exceed state standards in Telephone Creek, which may limit the distribution and success of salmonid fish, especially bull trout. In 2001, a maximum water temperature of 69.5°F was recorded during July; the 7-day average temperatures commonly exceeded 65°F.

The MDT rated water quality in Telephone Creek as not properly functioning because of high water temperatures and sediment from I-90.

**Fish Species and Aquatic Habitat Linkages**

Aquatic surveys (WSDOT 2002b) at Telephone Creek indicate that the culvert passing under I-90 is a complete barrier to fish passage, and, therefore, the upstream portion was not surveyed. Downstream of I-90, Telephone Creek contained brook trout and redside shiners.

The amount of large woody debris is low above Forest Service Road 4823 and high below the road, where the creek meanders through a forested wetland complex associated with the Yakima River floodplain. As a result, habitat complexity above Forest Service Road 4823 is low, but it is high below the road. Telephone Creek below Forest Service Road 4823 was not investigated due to the complex network of channels, ponds, and wetlands that make up the forested wetland. Except for the cleared power line corridor, riparian vegetation is moderately developed downstream of I-90. However, recent logging activities near the power lines have probably worsened conditions.

The MDT determined that Telephone Creek’s aquatic habitat was not properly functioning. The stream channel is confined above I-90 and unconfined below I-90. Multiple barriers exist, including the “U-Fish facility,” I-90 itself, the power line corridor, seasonal low water flow, and old roads in the area. The risk of debris flow from floods is high, and the stream channel above the highway is unstable. Debris passage should be provided with a structure that meets WDFW’s “stream simulation” criteria, in which the structure spans from bank to bank of the existing channel.

**What are the objectives at Telephone Creek?**

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the Pacific silver fir/western hemlock species assemblage zone. Year-round connectivity would require high structures (minimum 16 feet) due to winter snowpack. High structures would provide light under the structures to support plant life and increase the openness of the structure.
- Build structures to provide connectivity for at least 35 species of mammals, 8 species of amphibians, and 14 species of mollusks documented or suspected to occur in the area (see list in Attachment 2). This is the only area where wolverine have been documented nearby.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Restore capacity for flow and debris passage at the Telephone Creek crossing.
- Allow unconfined channel development downstream of I-90.
- Connect natural talus habitat on both sides of the highway.

**What potential design options did we evaluate at Telephone Creek?**

One design is under consideration at Telephone Creek (Exhibit 3.12-2). The option shown is conceptual and reflects current design at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Culvert dimensions are approximate. They will be sized to meet WDFW stream simulation requirements for fish passage.)

**Option A**

Option A would install a bottomless culvert at Telephone Creek designed with a width that meets WDFW stream simulation requirements and provides for debris flow passage. Its height would be optimized to facilitate wildlife movement within the constraint of the road profile and to provide a natural substrate. Preliminary designs indicate that this CEA would require at least a 4-foot by 4-foot culvert.

**How will the options perform?**

The MDT did not specify a wildlife connectivity objective for this location. This reflects the severe design constraints imposed by steep terrain. I-90 is cut into the base of Amabalis Mountain, resulting in steep cut slopes on the north side and steep fill embankments on the south side of the highway (Singleton and Lehmkuhl 2000). Proposed widening of the highway may lead to even higher cut slopes and fills. The steep slope of the terrain limits the amount of clearance available for crossing structures under westbound lanes. Overcrossings are not possible because the ground surface south of the highway slopes away too rapidly. These constraints preclude installation of structures with sufficient clearance and openness to accommodate large, high-mobility species.

Reviewers of previous drafts of this recommendation package have recommended that an attempt be made to obtain wildlife connectivity in the area of the Amabalis Mountain CEAs. The MDT acknowledges that crossing structures with attributes conducive to use by a full range of wildlife species are
desirable in this area. This perspective is supported by the likelihood that habitat conditions in this area will improve as previously logged areas are reforested. We also recognize that baseline monitoring information indicates carnivores (coyote, bobcat, and black bear) are regularly detected in this area (Singleton and Lehmkuhl 2000).

Some evidence suggests that providing crossing structures suitable for large, high-mobility species may not be as critical for the Amabalis Mountain CEAs as it is for other CEAs. For instance, ungulate roadkill information indicates a gap (drop in roadkill) between MP 64 and MP 67, corresponding to the area where this CEA is located, suggesting that steep terrain in the area may limit ungulate access to the highway (Singleton and Lehmkuhl 2000). Also, carnivore species found in the area are known to use crossing structures with limited openness, based on monitoring studies of crossing structures at other locations (reviewed in Forman et al. 2003).

Given that constructability constraints preclude large crossing structures in this CEA, we recommend that, in the area of the Amabalis Mountain CEAs, every effort be made to place small crossing structures wherever constructability allows. At minimum, this would accommodate occasional crossing by many of the smaller terrestrial species present in the area.
The proposed design option at this CEA would meet hydrologic connectivity objectives because it would allow for adequate debris passage. See Exhibit 3.12-3 at the end of this section for an evaluation of this CEA’s option.

**Performance Standards**

Site-specific performance standards that apply to this CEA will be determined at a later date (see Attachment 3).

**Are there other potential restoration opportunities?**

- Improve fish access to aquatic habitat by removing passage barriers on private lands (e.g., the U-fish facility downstream of I-90) and public lands (e.g., power line corridor, barrier falls, and old road crossings with no culverts) (WSDOT 2002b).
- Reduce recreational impacts on the stream channel and riparian areas.
## Telephone Creek Option Comparison Table
### Exhibit 3.12-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of Crossing Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>This CEA’s steep terrain and large clear-cuts north of highway currently limit habitat permeability.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>No</td>
<td>Minimum 4-foot by 4-foot culvert.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>No</td>
<td>No native soil or vegetation development possible within structure.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>No</td>
<td>This option would only link aquatic habitat.</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>North of highway, steep terrain limits access and use. South of highway, some residential development and developed recreation sites.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td>Majority is publicly owned, but private parcels south of the highway are heavily impacted.</td>
</tr>
<tr>
<td><strong>Hydrologic Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s culvert would accommodate movement of debris and water for typical watershed delivery. There is some risk of debris blockage from infrequent mass wasting events on Amabalis Mountain.</td>
</tr>
</tbody>
</table>
## Telephone Creek Option Comparison Table
### Exhibit 3.12-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>A</td>
<td>Yes</td>
<td>This option would provide for channel migration downstream of I-90. Channel is naturally confined upstream of I-90.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s culvert would convey naturally channelized flow to wetlands and unconfined areas downstream. We recommend a bottomless culvert instead of a box culvert to provide better surface and subsurface flow characteristics.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>No</td>
<td>The roadbed would fill the Telephone Creek floodplain within the new right-of-way.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>No</td>
<td>This option’s roadbed would fill the Telephone Creek floodplain within the new right-of-way.</td>
</tr>
</tbody>
</table>
What are the conditions at Hudson Creek?

The Hudson Creek CEA (Exhibit 3.13-1) is located between MP 66.8 and MP 67.3. The creek drainage area is 903 acres. The stream is partly canopied below I-90 but opens up within a power line corridor. Hudson Creek passes through a long 2-foot-diameter concrete culvert under I-90 and is a complete barrier to fish passage at all flows. The creek empties into the Yakima River. Over the years, Hudson Creek has been affected by logging activities and the construction of I-90, Forest Service Road 4823, and power line corridors. The Hudson Creek CEA includes several HCZs that link seepage zones upslope of I-90 to shallow aquifers and wetlands on the terrace below I-90.

**Vegetation Community**

The important habitats in the Hudson Creek CEA include Hudson Creek, and talus, riparian, wetland, and mature forest. The forest habitat in the area is Western Hemlock Series, grading into Grand Fir Series at drier sites in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. This CEA includes a soil type that is associated with a high diversity of
rare fungi (Garvey-Darda and Worthington 2003). This is the only CEA with talus habitats on both sides of I-90. Many species depend on talus, including pika and Larch Mountain salamander. Herrington (1988) found that 60 percent of the amphibians and reptiles in Oregon and Washington used talus habitats to moderate the effects of adverse seasonal weather conditions and for reproductive activities. The Hudson Creek CEA provides the opportunity to link talus, riparian, wetland, and mature forest habitats.

Wildlife and Terrestrial Species Linkages

The Hudson Creek CEA provides the best opportunity to provide linkage for species associated with talus habitat such as a variety of amphibians, including Larch Mountain salamander and _Ensatina_, alligator lizard, pika, marmot, and a host of lichen, bryophyte, and vascular plants. This CEA also has the potential to provide linkage for a large assemblage of high- and low-mobility species, including common species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, lizards, salamanders, and terrestrial mollusks, as well as many rare species such as wolverine, lynx, and gray wolf. This area provides the opportunity to link soils associated with a number of rare fungi.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2.

Wolverine tracks were documented on Amabalis Mountain approximately 1 mile north of I-90 in March 1998 (Singleton and Lehmkuhl [2000]). The species detected from automatic camera stations and snowtrack surveys in this general area include mule deer, elk, bobcat, coyote, Douglas squirrel, northern flying squirrel, and snowshoe hare. Also found during surveying were Pacific giant salamander and Cascades frog (WSDOT 2002b).

Mollusks found during project surveys include _Ancotrema sportella, Haplotrema vancouveriense, Ariolimax columbianus columbianus, Pristiloma sp.,_ and _Prophysaon vanattae_ (WSDOT 2002b).
In the Hudson Creek CEA, dominant soils and the rare and/or commercially important fungi species associated with these soils are as follows (USFS 1994; USFS 2003):

- **K254** Kachess gravelly sandy loam, 5 to 25 percent slopes. Fungi species associated with this soil type are *Acanthophysium farlowii, Boletus mirabilis, Boletus piperatus, Cantharellus subabidus, Dentinum repandum, Gomphus clavatus, Hericium abietis, Hygrophorus bakerensis, Laetioporus sulphureus, Morchella angusticeps, Ramaria araispora, Spathularia flavida*, and *Tricholoma magnivelare*.

- **K347** Gilpar sandy loam. Fungi species associated with this soil type are *Boletus mirabilis, Gyromitra californica, Morchella angusticeps*, and *Ramaria rasilispora*. This soil type occurs north of Hudson Creek, as well as in Cedar Creek and Telephone Creek.

- **K259** Fluvaquents 0 to 2 percent slopes. Fungi species associated with this soil type are *Cantharellus subalbidus* and *Laetioporus sulphureus*.
The road density in the Hudson Creek subwatershed is 3.8 miles of road per square mile. USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

The Hudson Creek area currently has low recreational use. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

The MDT characterized the terrestrial habitat in the Hudson Creek area as properly functioning, although the terrestrial linkages were not properly functioning because of the power line corridor, road density in the area, and recreational use. A soil type important to low-mobility species, Kachess Gravelly sandy loam (soil type K254), is present in the Hudson Creek CEA east of I-90.

**Stream Channel Function**

Hudson Creek has a watershed area of approximately 903 acres. The highway occupies a transition from Naches Formation rocks on the southern flank of Amabalis Mountain to an alluvial terrace above the Yakima River. Historically, shallow groundwater and seeps flowed off the hillside onto the terrace, recharging downslope wetlands and aquifers. Construction of highway cut slopes and drainage ditches have intercepted and redirected this flow into three small culverts under I-90, which have concentrated flow into the three channels that now form the branches of Hudson Creek.

Above I-90, Hudson Creek is a small headwater channel too small and steep to support fish. Most of the flow in Hudson Creek is from tributaries downstream of I-90.

Substrate in Hudson Creek is predominantly gravel, followed by fines, but the substrate is not embedded. Substrate particle distribution measurements were taken in two locations below I-90 (WSDOT 2002b). Both samples were taken above major areas of disturbance (power line corridor and roads). The upper site was closer to I-90 than the lower site. Both sites indicated a high proportion of fine sediment (less than 0.04 inch), although the sediment sources appeared to include gravel roads and eroding power line routes in addition to I-90 roadway runoff.

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1 Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
Wetlands
The Hudson Creek CEA contains Category II and III wetlands. The new road alignment would cross several large wetland complexes on the southwest side of I-90. These wetland areas may currently receive some highway runoff from I-90 and would directly benefit from stormwater treatment facilities that are planned for the new roadway.

Water Quality
Summer water temperatures in Hudson Creek exceed state standards, which may limit the distribution and success of salmonid fish, especially bull trout. In 2001, a maximum water temperature of 63°F was recorded during August. Partial temperature data for Hudson Creek suggest a large daily range in temperatures due to inadequate riparian cover in the area above Forest Service Road 4823.

The MDT rated water quality in Hudson Creek as not properly functioning because of high water temperatures, inadequate shade, and fine sediment from I-90 and other sources.

Fish Species and Aquatic Habitat Linkages
Downstream of I-90, Hudson Creek provides habitat for numerous fish species. During aquatic surveys, sculpins and cutthroat, brook, and rainbow trout were identified (WSDOT 2002b). The area upstream of I-90 was not included in aquatic surveys based on barriers to species’ movement.

Downstream of the project area, Hudson Creek flows through a large power line corridor and is crisscrossed by a small network of abandoned roads before meandering into the Yakima River floodplain. Except for the roads and power line clearing, the creek is well shaded and has good large woody debris recruitment potential. Although temperature data were incomplete, high temperatures are probably limiting use of the creek by fish. Stream conditions are similar to Telephone Creek.

A significant amount of large woody debris is present in Hudson Creek, and, because of this, habitat complexity is quite high. Hudson Creek converges with the Yakima River 7,578 feet downstream from I-90. Riparian vegetation is well developed between the Yakima River and Forest Service Road 4823 due to the Yakima River floodplain. Above, Forest Service Road 4823 conditions diminish due to the small road network and power line corridors crisscrossing the area.

Hudson Creek’s aquatic habitat is not properly functioning because of increased peak flows from highway runoff. Hudson Creek’s stream channel has been altered due to peak flows, and fine sediment has increased in the reach downstream of the highway. The MDT determined that the stream channel was artificially confined, although the Aquatic Species Discipline Report (WSDOT 2002b) stated that the stream channel was unconfined. There is a culvert barrier above I-90 and multiple barriers below I-90. The highway has caused Hudson Creek to channelize upslope of I-90.
What are the objectives at Hudson Creek?

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the Pacific silver fir/western hemlock species assemblage zone. Year-round connectivity would require high structures due to winter snowpack (12-foot clearance plus 4-foot average snowpack, for a total clearance of 16 feet). High structures would provide light under the structures to support plant life and increase the openness of the structure.
- Build structures to provide connectivity for at least 36 species of mammals, 9 species of amphibians, and 19 species of mollusks documented or suspected to occur in the area (see Attachment 2).
- Connect special soil type (K254) and the associated low-mobility species.
- Replace habitat connections for talus-associated species, wolverines, and possibly mountain goats.
- Provide passage for fish and other aquatic organisms moving throughout the stream system.
- Reconnect small wetlands and riparian habitats.
- Restore seepage and shallow groundwater flow paths that are currently intercepted by highway drainage systems and culverts.
- Improve channel functions at the east fork of Hudson Creek to allow natural channel development downslope of I-90.

What design options did we evaluate at Hudson Creek?

Exhibit 3.13-2 shows the options designed for Hudson Creek. The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment. Culvert dimensions are approximate. They will be sized to meet WDFW stream simulation requirements for fish passage.

Option A

Option A would construct twin bridges (approximately 240 feet long) with an approximate vertical clearance ranging from 19 to 23 feet across the largest fork of Hudson Creek. Truck-climbing lanes in both directions would increase the width of these bridges to about 72 feet. In addition to the bridge, two HCZs were identified for this option to maintain hydrologic connections at the forks of Hudson Creek (Exhibit 3.13-2a).
Hudson Creek CEA, Option A
Exhibit 3.13-2a

Hudson Creek CEA, Option B
Exhibit 3.13-2b
Option B

Option B would construct twin bridges (approximately 120 feet long) with an approximate vertical clearance ranging from 21 to 22 feet across a fork of Hudson Creek. In addition to the bridge, three HCZs were identified for this option to maintain hydrologic connections at the forks of Hudson Creek (Exhibit 3.13-2b).

Option C

Option C would install a bottomless culvert (approximately 4 feet by 4 feet) at a fork of Hudson Creek designed with a width that meets WDFW stream simulation requirements and provides for debris flow passage (Exhibit 3.13-2c). The same three HCZs identified in Option B also apply to this option.

How will the options perform?

This area provides for connectivity between several habitat types, including fine-scale habitat features such as talus. The crossing structures in this area should
provide for terrestrial passage, as well as surface and subsurface water flows. To the east, the nearest proposed large crossing structure is about 3 miles away at the Toll Creek CEA.

The realignment of the road to provide greater clearance within crossing structures at this CEA would increase effects on mature forest to the east—the taller the structure, the more impacts on the forest. This effect needs to be balanced with the benefits that taller structures offer in terms of providing crossing opportunities for a wider range of species. We recommend the greater height. clearance (as designed) within the crossing structures at this location despite effects on adjacent mature forest habitat because:

- Highway structures would have a design life of up to 70 years, a period of time that is long enough for forests to redevelop structural components of late-successional habitat in the favorable growth conditions of the project area.

- Habitat components not found in other CEAs are found in the Hudson Creek CEA.

- The spatial extent of realignment effects on late-successional habitats are limited.

To fully support the development of successful designs, more information is needed regarding:

- Groundwater monitoring and analysis of the shallow groundwater flow system in the Hudson Creek area. This information will be useful in refining the designs and locations of HCZs.

- Locations of the streams and seepage zones in this area. These are generally small and intermittent, and are difficult to map accurately on plan drawings. Field surveys can readily address this information need.

**Option A**

Option A would provide for the overall wildlife connectivity objectives at this location. The clearance within this crossing structure would range from 19 to 23 feet. This increased clearance is important for maintaining crossing structure openness given the greater width of bridges associated with truck-climbing lanes. The 240-foot bridges provide linkages for talus, wetland, riparian, and upland habitats. Human disturbance adjacent to this area is low, which would increase the likelihood of use by animals.

This option meets the hydrologic connectivity objectives for this CEA. HCZs at seepage zones would restore natural flow paths to shallow aquifers and wetlands on the south side of the highway. A bridge over the largest fork of Hudson Creek would restore unconfined flow patterns and allow natural channel development downslope of I-90. Retaining walls or other measures should be taken to minimize fill that the new road alignment would place in Wetland LE on the
south side of the highway. The retaining wall designs should consider and minimize potential impacts on subsurface flows and hydrologic processes.

**Option B**

Option B does not meet wildlife connectivity objectives. The bridge does not provide adequate space underneath to provide talus habitat, as well as open travel routes for high-mobility species.

This option meets hydrologic connectivity objectives and has hydrologic benefits and impacts similar to Option A. The bridge over the largest fork of Hudson Creek is shorter than in Option A, but would provide sufficient width of unconfined flow if vertical abutments are used.

**Option C**

The culvert proposed in Option C for the main fork of Hudson Creek would not meet wildlife connectivity objectives. The 4-foot by 4-foot bottomless culvert does not have the size attributes known to encourage use by high-mobility species, and it is not large enough to link habitats, including the talus habitat type that is present in this CEA, but not in any others.

This option does not meet hydrologic connectivity objectives. The 4-foot by 4-foot bottomless culvert at the largest fork of Hudson Creek would not restore shallow subsurface flow across the highway, and would confine the channel. A pair of large bottomless culverts could address this concern by providing a wider area of unconfined surface and shallow subsurface flow.

See Exhibit 3.13-3 at the end of this section for a detailed comparison of the options at the Hudson Creek CEA.

**Performance Standards**

All performance standards apply to the Hudson Creek CEA (see Attachment 3).

**Are there other potential restoration opportunities?**

- Restore riparian vegetation in the power line corridor to enhance stream shade, sediment filtering, bank stability, and organic nutrient inputs (in cooperation with entities transmitting electricity through the corridor). This would also enhance habitat continuity for wildlife species associated with riparian habitats and improve access to I-90 crossing structures.

- Improve fish passage at culverts downstream of I-90 (i.e., power line service road and Forest Service Road 4823) (WSDOT 2002b).
### Hudson Creek Options Comparison Table
Exhibit 3.13-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>Only location for connecting talus. Nearby sightings of wolverine and many other high-mobility species.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>Yes</td>
<td>This is a reach with very few crossing opportunities.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>This option does not provide adequate space under the bridge to provide talus habitat as well as open travel routes for high-mobility species. Talus inside the structure would further limit useful width for high-mobility species. This is an area with possible movement by mountain goat. Clevenger (2005) recommends 14 to 15 feet for high-mobility species and a structure wider than 120 feet.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>No high-mobility species connectivity. No connection for species of concern.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>Yes</td>
<td>Talus species are connected. Slope of terrain would allow more light penetration to support plants under structures.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Talus species are connected, although this may limit width of non-talus habitat. Slope of terrain would allow more light penetration to support plants under structures.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>No connection for species of concern.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>Yes</td>
<td>Species associated with talus, wetland, riparian, and upland forest habitat are connected at this location.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Species associated with talus, wetlands, riparian, and upland forest habitat are connected at this location.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>No connection for riparian, upland forest, or talus habitat.</td>
</tr>
</tbody>
</table>
### Hudson Creek Options Comparison Table
Exhibit 3.13-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>This option would limit accessibility for humans.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

#### Hydrologic Connectivity

| Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats? | A | Yes | This option’s bridge over the main fork would restore channel complexity, debris capacity, energy dissipation, and natural flow regime. |
| | B | Yes | Same as Option A. |
| | C | Yes | This option’s culvert would provide minimally adequate debris capacity and energy dissipation (assuming bottom is roughened and proper outlet control is installed). |
| Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans? | A | Yes | Bridging of the main fork of Hudson Creek would reduce flow concentration and allow natural movement of the channel. |
| | B | Yes | Same as Option A. |
| | C | Yes | This option’s culvert would allow minimal channel movement within the right-of-way, but would restore downslope channel migration. |
| Does this option avoid impacts on wetland hydroperiods? | A | Yes | The HCZs would convey and disperse water from upslope seepage faces, and would not drain upslope wetland areas (some artificial linear wetland features currently exist, but would be removed by highway construction). |
| | B | Yes | Same as Option A. |
| | C | Yes | Same as Option A. |
| Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands? | A | N/A | |
| | B | N/A | |
| | C | N/A | |
| Does this option restore natural surface and subsurface flow paths through the I-90 roadbed? | A | Yes | This option’s bridge at the main fork would restore natural surface and subsurface flow paths under 240 feet of roadway, which would, in turn, restore natural flow to a wetland on the downstream alluvial terrace. HCZs would restore subsurface flow through the roadbed from seepage and shallow groundwater zones east and west of the main fork. |
| | B | Yes | Same as Option A, except only 120 feet of surface and subsurface flow paths would be restored. Vertical abutments should be used to maximize the width of unconfined flow beneath the bridge. |
## Hudson Creek Options Comparison Table
*Exhibit 3.13-3*

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>C</td>
<td>No</td>
<td>This option’s 4-foot by 4-foot culvert at the main fork does not restore shallow subsurface flow paths. A pair of large bottomless culverts could address this issue by restoring a wider area of unconfined surface flow and shallow subsurface flow.</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Yes</td>
<td>This option would remove fill from 240 feet of riparian area and shallow groundwater zones at the main fork of Hudson Creek. The new road alignment for all three options would place new fill in Wetland LE, but the area of fill would be minimized using retaining walls or other measures to reduce the road footprint.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option would remove fill from 120 feet of riparian area and shallow groundwater zones at the main fork of Hudson Creek. The new road alignment for all three options would place new fill in Wetland LE, but the area of fill would be minimized using retaining walls or other measures to reduce the road footprint.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option’s culvert does not avoid fill in the main fork valley. The new road alignment for all three options would place new fill in Wetland LE, but the area of fill would be minimized using retaining walls or other measures to reduce the road footprint.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>This option would remove compacted fill from 240 feet of floodplain and seepage zones associated with the main fork of Hudson Creek. Retaining walls or other measures should be considered to minimize fill that the new road alignment would place in Wetland LE on the south side of the highway.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>This option would remove compacted fill from 120 feet of floodplain and seepage zones associated with the main fork of Hudson Creek. Retaining walls or other measures should be considered to minimize fill that the new road alignment would place in Wetland LE on the south side of the highway.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>This option would fill in shallow groundwater area at the Hudson Creek main fork. Retaining walls or other measures should be considered to minimize fill that the new road alignment would place in Wetland LE on the south side of the highway.</td>
</tr>
</tbody>
</table>
3.14 Easton Hill CEA

What are the conditions at Easton Hill?

The Easton Hill CEA (Exhibit 3.14-1) is located between MP 67.3 and MP 68.0. Easton Hill is a broad, forested slope. I-90 is a widely divided highway in this CEA, with a forested median that is unique within the project area. The Easton Hill area is transitional between the dry forest types to the east and more mesic forests to the west. In the eastern portion of the project area, topography and human disturbance appear to channel animals onto the east slope of Amabalis Mountain at Easton Hill between MP 67 and MP 69. This area was identified as the most permeable area for late-successional-associated species moving through the project area (Singleton and Lehmkuhl 2000). This area lacks defined stream channels. The Easton Hill CEA includes one HCZ that links the wetland areas that are bisected by the westbound lanes of I-90.

Location of Easton Hill CEA
Exhibit 3.14-1

Vegetation Community

The important habitats in the Easton Hill CEA include wetland and mature forest. The forest habitat in the area is Western Hemlock Series, grading into Grand Fir Series at drier sites in the drainage (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. One wetland located at the west end of the median was of relatively high quality and
contained a diverse plant community. The dominant plants are red alder, vine maple, skunk cabbage, lady fern, and hedge nettle. Western redcedar, black cottonwood, prickly currant, red-osier dogwood, salmonberry, Nootka rose, short Oregon grape, small-fruited bulrush, false hellebore, starry false lily of the valley, feathery false lily of the valley, stream violet, baneberry, foam flower, common horsetail, small unknown sedge, bracken fern, sword fern, and devils club constitute the non-dominant plants. This CEA includes a soil type that is associated with a high diversity of rare fungi (Garvey-Darda and Worthington 2003). The Easton Hill CEA provides the opportunity to link forest and wetland habitat and the species associated with these habitats on both sides of I-90.

**Wildlife/Terrestrial Species Linkages**

The Easton Hill CEA along with the Kachess River/Lake Easton CEA provides critical linkage between high quality habitats associated with the roadless areas south of I-90 to roadless areas located between Kachess Lake and Lake Cle Elum, which in turn link to the Alpine Lakes Wilderness. These roadless areas are particularly important for rare wide-ranging species sensitive to high road densities such as wolverine, fisher, gray wolf, and grizzly bear. This CEA also provides the opportunity to link a host of species or subspecies that are unique to the eastern portion of the project area, including western skink, western fence lizard, northern alligator lizard, gopher snake, yellow-pine chipmunk (*Tamias amoenus affinis*), and Beechey’s ground squirrel (*Spermophilus beecheyi*). This CEA can also provide linkage for an assemblage of more common high- and low-mobility species, such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, salamanders, frogs, and terrestrial mollusks. Exhibit 3.14-2 shows a view of the Easton Hill and Kachess River/Lake Easton CEAs.

Easton Hill has the highest concentration of elk collisions in the project area (Singleton and Lehmkuhl 2000). The Easton Hill area has been identified as the best-connected habitat linkage for old growth forest species in landscape modeling. Collisions with elk in the area occurred during all seasons. Deer were hit in this area during all seasons except winter. A black bear was killed in a collision near MP 67.5 near the top of Easton Hill in early summer 2002. Species of small mammals, amphibians, reptiles, and terrestrial mollusks in the project area, based on surveys and/or museum specimens collected in the area, are listed in Attachment 2.

During automatic camera surveys, Singleton and Lehmkuhl (2000) identified deer, elk, bobcat, black bear, Douglas squirrel, northern flying squirrel, snowshoe hare, coyote, and striped skunk. Although it is unlikely that fish habitat is available in the Easton Hill CEA, the area may contain adequate habitat elements for amphibian and reptile species. *Ensatina eschscholtzii*, a strictly terrestrial salamander, has been documented here (Garvey-Darda pers. comm. 2005).
Mollusks found during surveys of the disturbance zone include *Ancotrema sportella*, *Haplotrema vancouverense*, *Prophysaon vanattae*, *Hemphillia dromedaries*, *Prophysaon dubium*, and *Vertigo columbiana*.

In the Easton Hill CEA, dominant soils and the rare and/or commercially important fungi species associated with these soils are as follows (USFS 1994; USFS 2003):

- **K241** Thetis gravelly sandy loam, 25 to 45 percent slopes. Fungi species associated with this soil type include *Morchella angusticeps*, *Boletus mirabilis*, and *Tricholoma magnivelare*.

- **K242** Boxer Gravelly Sandy Loam, 25 to 45 percent slopes. Associated fungi species are *Ganoderma tsugae*, *Hygrophorus bakerensis*, and *Tricholoma magnivelare*.

- **K254** Kachess Gravelly sandy loam, 5 to 25 percent slopes. Fungi species associated with this soil type include *Acatophusium farlowii*, *Boletus mirabilis*, *Boletus piperatus*, *Cantharellus subabidus*, *Dentinum repandum*, *Gomphus clavatus*, *Hericium abietis*, *Hygrophorus bakerensis*, *Laetiporus sulphureus*, *Morchella angusticeps*, *Ramaria araispora*, *Spathularia flavida*, and *Tricholoma magnivelar*.

The road density in the Easton Hill subwatershed is 3.8 miles of road per square mile.¹ USFS has committed to reducing road densities to less than 2.0 miles of road per square mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

¹ Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
The Easton Hill area currently has low recreational use. Appropriate management of recreation in the area will be important to maintaining the habitat effectiveness of the area.

**Stream Channel Function**

No streams are present at the Easton Hill CEA.

**Wetlands**

The Easton Hill CEA contains Category I, II, and III wetlands that are not associated with stream drainage. One wetland located at the west end of the I-90 median is of relatively high quality and contains a diverse plant community. The dominant plants are red alder, vine maple, skunk cabbage, lady fern, and hedge nettle. Western redcedar, black cottonwood, prickly currant, red-osier dogwood, salmonberry, Nootka rose, short Oregon grape, small-fruited bulrush, false hellebore, starry false lily of the valley, feathery false lily of the valley, stream violet, baneberry, foam flower, common horsetail, small unknown sedge, bracken fern, sword fern, and devil's club constitute the non-dominant plants.

**Water Quality**

No streams are present in the Easton Hill CEA.

**Fish Species and Aquatic Habitat Linkages**

No streams are present in the Easton Hill CEA, and it is unlikely that fish habitat is available.

Aquatic surveys were not conducted in the Easton Hill CEA because of the absence of defined channels. Based on the lack of aquatic components, the MDT did not rate this section.

**What are the objectives at Easton Hill?**

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the grand fir and Douglas fir associations.
- Link late successional-associated species to roadless areas in an area of relatively high habitat connectivity.
- Connect special soil type K254 and the associated low-mobility species.
- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.
- Provide connections for species associated with aquatic habitat.
- Restore surface and subsurface flow paths connecting wetland areas bisected by the westbound lanes of I-90.
What design options did we evaluate at Easton Hill?

Exhibit 3.14-3 shows the design options for Easton Hill. The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment. Additional clearance beneath the 120-foot bridges may be possible depending on the level of excavations.

Option A

Option A would flatten the westbound curve near the top of Easton Hill using a curve that meets current design standards. Two 120-foot-long bridges would be constructed in both directions over a natural draw in the vicinity of MP 67.8. Approximate clearance would be approximately 12 to 14 feet under the westbound bridge and 14 to 15 feet under the eastbound bridge. The westbound bridge span would be approximately 72 feet wide to accommodate a truck-climbing lane (compared to 60 feet wide for structures with three lanes and shoulders) (Exhibit 3.14-3a).

Option B

Option B would flatten the westbound curve near the top of Easton Hill using a curve that meets current design standards. A wildlife overcrossing structure about 150 feet wide and 350 feet long would be constructed at MP 67.5 over both directions of travel. An HCZ was identified to connect two wetlands split by the westbound I-90 lanes (Exhibit 3.14-3b).

Option C

Option C would flatten the westbound curve near the top of Easton Hill using a curve that meets current design standards. A wildlife overcrossing structure approximately 150 feet wide and 120 feet long would be constructed over the westbound lanes near MP 67.9, and a bridge, approximately 120 feet long providing about 15 feet of vertical clearance, would be constructed in the eastbound lanes over an existing draw near MP 67.8. The same HCZ identified in Option B also applies to this option (Exhibit 3.14-3c).

How will the options perform?

Studies of wildlife movement and habitat quality indicate the Easton Hill CEA is an important area to create linkages for high-mobility species that merits special
Easton Hill CEA, Option A
Exhibit 3.14-3a

Easton Hill CEA, Option B
Exhibit 3.14-3b
attention for connectivity, even though there are no stream crossings or structures needed for other purposes. This CEA may provide the only large crossing in the Douglas-fir and grand fir associations (depending upon which option is constructed at the Kachess River/Lake Easton CEA). Hydrologic concerns here are limited to the shallow subsurface and surface flows associated with the wetland in the median area.

**Option A**

Option A would provide for the overall wildlife connectivity objectives at this location. This finding includes the assumption that a minimum of 16 feet vertical clearance can be obtained at the bridge on westbound lanes. This amount of clearance is particularly important at this CEA, which is intended to provide connectivity for large, high-mobility species, and because additional bridge width due to four travel lanes reduces structure openness.

This option meets hydrologic connectivity objectives by constructing a bridge across wetlands on the westbound lanes of I-90. This would reduce fill placement in wetlands and maintain flow paths between wetlands on both sides of the westbound lanes. Retaining walls or other measures should be used to minimize the area of fill placed in Wetland AM for the realigned westbound lane. There
may also be opportunities to construct wetlands in areas where the old roadbed is removed for the realignment of the westbound lanes.

Wetland impacts would likely occur from building a crossing on the westbound lanes in Option A. Since this structure may be a seasonally “wet crossing” structure, additional measures may be needed for small animals that need dry conditions for movement.

**Option B**

Option B meets wildlife connectivity objectives. Compared to Option A, Option B has the benefits of unlimited openness provided by a wildlife overcrossing, better opportunities to buffer the structure from noise and light coming from the highway, and, because it is located where lane alignments converge, provides a shorter crossing. This option aligns well with ridgeline travel paths, but field surveys suggest the current level of use may not be as high as the Option A pathway. Linkage to the Kachess River/Lake Easton CEA is reduced. This overcrossing would not meet connectivity needs of wetland-associated species; however, medium crossing structures located at the HCZ would provide connectivity for these species.

This option meets hydrologic connectivity objectives, with benefits similar to Option A except that an HCZ would be used in place of a bridge to maintain wetland flow paths across the westbound lanes of I-90. This would increase the amount of fill placed in wetlands beneath the new road alignment, and would provide less continuous wetland flow.

**Option C**

Option C meets wildlife connectivity objectives. Compared to Option A, use of an animal overcrossing for the westbound lanes eliminates clearance issues and provides for better buffering of disturbances coming from the highway. However, Option C, like Option B, may not meet the connectivity needs of wetland-associated low-mobility species. Compared to Option B, this option yields a longer crossing, and the effectiveness of an “under-over” crossing structure combination with a wide median is untested and uncertain.

This option meets hydrologic connectivity objectives and has hydrologic benefits and impacts similar to Option B.

See Exhibit 3.14-4 at the end of this section for an in-depth comparison of the options.

**Performance Standards**

All performance standards apply to the Easton Hill CEA, except Mitigation Performance Standards 4.1, 4.2, and 4.5 (see Attachment 3).
Are there other potential restoration opportunities?

- Identify and acquire private land, and transfer it to public ownership. Manage acquired parcels to maintain or improve habitat integrity and promote wildlife access to the Easton Hill crossing structures (e.g., parcels in Sections 19 and 20, T. 21 N., R. 13 E.W.M., and parcels in T. 20 N., R. 13 E.W.M.).

- Manage habitat on USFS lands near Easton Hill to improve habitat value for Canada lynx. This approach to habitat management would capitalize on existing topographic potential for lynx use of the Easton Hill crossing structure and would be compatible with use of this structure by many other high-mobility species that are habitat generalists.
### Easton Hill Options Comparison Table

Exhibit 3.14-4

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of Crossing Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>Location coincides with a high roadkill zone and an area of relatively high habitat permeability identified by Singleton and Lehmkuhl (2000). Linkage to roadless areas in Silver Creek drainage that link to Alpine Lakes Wilderness. Aligns well with established wildlife path.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Attributes of Crossing Structure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>Yes</td>
<td>Opportunities not as good as an overcrossing. Location of undercrossings in vegetated draws would provide some natural sound and light attenuation, but this buffering effect is not profound. Wide separation of lanes would also reduce sound intensity. Vegetation not as effective as earthen berms at blocking both noise and light.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Berms on edges of overcrossings can provide effective buffer from noise and light.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Westbound overcrossing would be less wide, but would still provide adequate space for noise-attenuating berms on edges.</td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>Yes</td>
<td>Yes, but would need to meet 16-foot minimum height on westbound bridge. Some information suggests a shorter overall crossing of the highway would lead to better crossing structure performance. This option has a wide median.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Overcrossing would provide best use by multiple terrestrial species.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Some information suggests a shorter overall crossing of the highway would lead to better crossing structure performance. This option has a wide median.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s wide median would provide improved lighting in structures.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Bottomless culverts at wetland needed to convey wetland-associated low-mobility species (e.g., frogs, aquatic salamanders). Native soils on overcrossing can help to move terrestrial low-mobility species (e.g., terrestrial mollusks).</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Bottomless culverts at wetland essential to convey wetland-associated low-mobility species.</td>
</tr>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>Yes</td>
<td>Yes, assuming dry culverts are included under westbound lanes to link terrestrial habitats and species (e.g., gopher snakes). The location of the bridges is important; the westbound bridge currently sited to span wetlands may not adequately link terrestrial habitats.</td>
</tr>
</tbody>
</table>
## Easton Hill Options Comparison Table
### Exhibit 3.14-4

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Bottomless culverts needed for wetland habitat.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Bottomless culverts needed for wetland habitat.</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>Yes</td>
<td>This CEA is near the eastern extent of National Forest land. There are fewer opportunities for effective crossing structures to the east.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td>This CEA is near the eastern extent of National Forest land. There are fewer opportunities for effective crossing structures to the east.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>

### Hydrologic Connectivity

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</td>
<td>A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</td>
<td>A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroporidies?</td>
<td>A</td>
<td>Yes</td>
<td>Elevations beneath the bridge should be carefully designed to avoid negative effects on upslope wetland.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The HCZ should be carefully designed based on groundwater monitoring data to avoid negative effects on upslope wetland.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option B.</td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>N/A</td>
<td>Not applicable because of the lower value of the upslope wetland. This option's bridge does restore continuous wetland flow between wetlands bisected by the westbound lanes.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>N/A</td>
<td>Not applicable because of the lower value of the upslope wetland. This option's HCZ does not restore continuous wetland flow between wetlands bisected by the westbound lanes.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td>Same as Option B.</td>
</tr>
</tbody>
</table>
## Easton Hill Options Comparison Table
**Exhibit 3.14-4**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>Yes</td>
<td>This option’s bridge would restore surface and shallow subsurface flow between two wetland areas.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>The HCZ would restore surface and shallow subsurface flow between two wetland areas.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option B.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>N/A</td>
<td>The new westbound road alignment would place new fill in Wetlands AM and DW, but the area of fill would be minimized using retaining walls or other measures to reduce the road footprint. This option would avoid filling wetland areas under 120 feet of the realigned westbound lanes.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>N/A</td>
<td>The new westbound road alignment would place new fill in Wetlands AM and DW, but the area of fill would be minimized using retaining walls or other measures to reduce the road footprint.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td>The new westbound road alignment would place new fill in Wetlands AM and DW, but the area of fill would be minimized using retaining walls or other measures to reduce the road footprint.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>The new westbound road alignment would place new fill in Wetlands AM and DW, but Option A minimizes this disturbance by bridging wetlands under 120 feet of roadway.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>This option’s westbound lane would disturb wetland soils on high-quality wetland in median area.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Same as Option B.</td>
</tr>
</tbody>
</table>
3.15 Kachess River/Lake Easton CEA

What are the conditions at Kachess River/Lake Easton?

The Kachess River/Lake Easton CEA (Exhibit 3.15-1) is located between MP 68.3 and MP 69.6. This area lies within a north-south trending habitat corridor that goes from the Silver Creek drainage (east of Kachess Lake), around the south end of Kachess Lake, crossing I-90 west of the Kachess River crossing, and then trending toward the southwest. The Kachess River watershed has 40,632 acres. I-90 spans the Kachess River with a 150-foot-long bridge westbound and a 99-foot-long bridge eastbound. From I-90, the Kachess River flows into Lake Easton. Lake Easton's outlet below the Lake Easton dam is the Yakima River.

Vegetation Community

The important habitats in the Kachess River/Lake Easton CEA include Kachess River, wetlands, and forest. The forest in the area is a mixture of Grand Fir and Western Hemlock series (Lillybridge et al. 1995; Garvey-Darda and Worthington 2003). The tree species within the Western Hemlock Series include Douglas-fir, western hemlock, grand fir, western redcedar, western white pine, and red alder. The tree species within the Grand Fir Series include Douglas-fir, grand fir, ponderosa pine, and lodgepole pine. The
western portion of the CEA occurs within the Western Hemlock Series and the eastern portion of the CEA occurs within the Grand Fir Series. This CEA includes a soil type that is associated with a high diversity of rare fungi (Garvey-Darda and Worthington 2003). This is the only CEA with the Grand Fir Series present. The Kachess River/Lake Easton CEA provides the opportunity to link forest, riparian, stream, and wetland habitat and the species associated with these habitats on both sides of I-90.

**Wildlife/Terrestrial Species Linkages**

The Kachess River/Lake Easton CEA lies within a north-south trending habitat corridor. Snow tracking and remote cameras indicate this is a high-use CEA that provides the only opportunity to link a host of bryophyte, lichen, fungi, and vascular plant species associated with the Grand Fir Series. This CEA provides the best opportunity to link a host of species or subspecies that are unique to the eastern portion of the project area, including western skink, western fence lizard, northern alligator lizard, gopher snake, yellow-pine chipmunk (*Tamias amoenus affinis*), mountain beaver (*Aplodontia rufa rainieri*), and Beechey’s ground squirrel (*Spermophilus beecheyi*). This CEA also provides the closest linkage to high-quality habitat associated with roadless areas south of I-90 to roadless areas located between Kachess Lake and Lake Cle Elum, which in turn link to the Alpine Lakes Wilderness. These roadless areas are particularly important for rare wide-ranging species sensitive to high road densities such as wolverine, fisher, gray wolf, and grizzly bear. This CEA can provide linkage for an assemblage of more common high- and low-mobility species such as deer, elk, black bear, mountain lion, coyote, fox, bobcat, raccoon, river otter, weasels, shrews, voles, snakes, salamanders, frogs and terrestrial mollusks.

Species of small mammals, amphibians, reptiles, and terrestrial mollusks in the project area based on surveys and/or museum specimens collected in the area are listed in Attachment 2.

The road density in the Kachess River subwatershed is 5.8 miles of road per square mile. USFS has committed to reducing road densities to less than 2.0 miles of road per square mile.1 USFS has committed to reducing road densities to less than 2.0 miles of road per square mile.

---

1 Road densities are considered a surrogate for human use. High road densities reduce the effectiveness of wildlife habitat, depending on the overall human use associated with the road. Roads may also act as movement barriers to a variety of wildlife species regardless of the level of human use.
mile in each subwatershed (USFS and USFWS 1997), which will improve landscape conditions in the future.

Appropriate management of recreation in the area will help improve the habitat effectiveness of the area.

Stream Channel Function

The Kachess River flows between Kachess Lake and Lake Easton, draining an area of 40,632 acres. Much of the watershed is forested, with the headwaters in the Alpine Lakes Wilderness.

Historically, the Kachess River connected Kachess Lake to the Yakima River. Kachess Lake was formed by a glacial moraine that impounded melting ice water during the Lakedale Drift 15,000 years ago. The Kachess Lake dam raised the lake level by 59 feet to provide flood control and storage for irrigation (HartCrowser 2002). Lake Easton dam was constructed to create a shallow reservoir for irrigation on the Yakima River floodplain; the lake inundated the historic mouth of the Kachess River. The hydrology of the lower Kachess River is now driven entirely by reservoir operations that preclude most natural channel functions.

Lake Easton is also part of the upper Yakima River system. The upper Yakima River flows into Lake Easton, and Lake Easton empties into the Yakima River. The Kittitas Reclamation District operates and maintains Lake Easton dam. Lake Easton has a storage capacity of 4,000 acre-feet.

The dominant substrate in Lake Easton is sand and mud.

Wetlands

The Kachess River/Lake Easton CEA has two small wetlands. A .38-acre Category III wetland is located in the median at MP 69.4 near the bridges over the Kachess River. This wetland was formed after construction of the existing highway. A 2-acre Category II wetland is located on the west side of the highway at MP 69.5.

Water Quality

Summer water temperatures in Lake Easton exceed state standards. In 2001, a maximum water temperature of 68.9°F was recorded during mid-July, and 7-day average temperatures were commonly above 60°F. Water temperatures in the lake exhibit a small daily range due to the large mass of water being stored. Surface temperatures would be expected to be higher and more variable. The high temperatures could limit populations of bull trout and other salmonids, although suitably cool waters probably exist in the lower depths of the lake.

In 2001, a maximum water temperature of 69.7°F was recorded in Kachess Lake during mid-July; 7-day average temperatures were commonly above 60°F. Elevated water temperatures in Kachess Lake result in elevated water
temperatures in the released water. The Kachess River exhibits a small daily range in temperatures because of the constant supply of relatively warm water from Kachess Lake and the short distance between the Kachess Lake dam and Lake Easton. These temperatures could limit populations of bull trout or other salmonids. The Kachess River below the dam receives large quantities of fine sediment from Kachess Lake.

The MDT rated water quality in the Kachess River/Lake Easton area as not properly functioning. Specific contributing factors include elevated water temperatures (lack of riparian vegetation), sediment (from I-90), and stormwater runoff.

**Fish Species and Aquatic Habitat Linkages**

Kachess River flows are managed for irrigation purposes and to allow river flows more favorable to fish in reaches of downstream rivers (such as the Yakima River). Spawning areas are limited due to the presence of large pools and only a few scattered riffles. The Kachess River watershed upstream of the dam is inaccessible to anadromous salmon because the dam has no fish passage facilities. In addition, the Kachess River is often dry near the Kachess dam during the late summer.

The Lake Easton dam has a fish ladder to enable fish passage, but passage is occasionally impaired. Lake Easton supports many species of fish, including salmonids and warm water game species such as bass. The lake is a migration corridor for salmonids moving up into the upper Yakima River watershed as well as lake tributaries.

The Kachess River was not included in aquatic surveys; however, it is very likely that this river contains most of the species found within the upper Yakima River, including salmonid species. The Yakima River is known to support anadromous runs of Chinook, coho, and steelhead trout, as well as bull trout. In addition, the habitat surrounding the lake and extending upstream past I-90 probably provides habitat for some aquatic-dependent amphibians.

The MDT determined that the aquatic habitat in the Kachess River/Lake Easton CEA is not properly functioning due to the upstream operation of the Kachess dam. The stream channels are influenced by reservoir water levels, the Kachess River channel is artificially confined, and I-90 has encroached on the Kachess River floodplain. The stream channels are not natural systems due to development that has occurred.

**What are the objectives at Kachess River/Lake Easton?**

- Significantly reduce animal-vehicle accidents in this high roadkill zone for deer and elk. This will require wildlife fencing around the crossing structures.

- Provide passage for fish and other aquatic organisms moving throughout the river system.
- Minimize negative impacts on the small wetland in the median of I-90 west of the Kachess River bridges.

- Provide a high level of year-round connectivity for high- and low-mobility species associated with the Douglas-fir and grand fir associations.

- Link late successional-associated species to roadless areas in an area of relatively high habitat connectivity.

### What potential design options did we evaluate at Kachess River/Lake Easton?

Exhibit 3.15-2 shows the design options for the Kachess River/Lake Easton CEA. The options shown are conceptual and reflect current designs at the time of printing. All locations, dimensions, and ground surface elevations are approximate. Within the bridge structures, vertical abutments or similar measures will be used to maximize openness and connect habitats, while minimizing wetland fill placement and noxious weed growth and treatment.

**Option A**

Option A would replace both the existing eastbound and westbound bridges over the county road at MP 69.0 with 120-foot-long bridges. These new bridges would provide a clearance of about 17 feet; the westbound bridge would be about 72 feet wide (rather than 60 feet) to accommodate a truck-climbing lane. Bridges over the Kachess River would be widened or replaced to provide an additional lane in each direction.

**Options B and C**

Options B and C would widen or replace the existing bridges at the county road at MP 69.0 and the bridges at Kachess River to provide an additional lane in each direction. The county road bridges would maintain existing clearances of 14 to 16 feet. Both westbound bridges would be about 72 feet wide (rather than 60 feet) to accommodate a truck-climbing lane.

**Option D**

Option D would construct wildlife overcrossing structures (approximately 150 feet wide) across both the eastbound and westbound lanes at approximately MP 68.5 and MP 68.4, respectively.

The same improvements proposed in Options B and C for the bridges over the county road and Kachess River would also apply to Option D.
Kachess River/Lake Easton CEA, Option A
Exhibit 3.15-2a

Kachess River/Lake Easton CEA, Options B and C
Exhibit 3.15-2b
How will the options perform?

This general area of the Kachess River/Lake Easton CEA has many of the same indicators of importance for wildlife connectivity as the top of Easton Hill, and represents the easternmost opportunity within the project boundaries to improve habitat linkages. This area is a high roadkill zone for deer and elk. Mountain lions also frequently cross the highway here and some have been killed. Structures in this CEA would provide ecological connectivity for the easternmost species assemblage in the project area, and would connect a large roadless area to the north with the Yakima River floodplain and public lands to the south. Public land ownership is limited to the east of the project boundary, making this CEA especially important for providing connectivity.

Option A

This option does not meet wildlife connectivity objectives. Although extending the bridges at the county road would provide a crossing structure with some physical attributes conducive to wildlife use, the high likelihood of increasing
vehicle traffic on the county road, impracticality of excluding wildlife from traveling on the county road, and the proximity of private development diminish the chances that this option would perform well for wildlife.

This option meets hydrologic connectivity objectives for this CEA. Natural channel and floodplain functions are limited by upstream and downstream reservoir operations, but the existing bridge provides adequate fish and debris passage. Vertical retaining walls on the highway shoulder would minimize new fill in wetlands along the west bank of the river.

**Options B and C**

Options B and C would not meet wildlife connectivity objectives. Improvements made to existing bridges in the CEA under these options would only provide benefits to transportation and would not enhance ecological connectivity. The attributes of the bridges after expansion to accommodate additional traffic lanes would not meet most of the performance standards used to evaluate crossing structure performance for wildlife.

These options meet hydrologic connectivity objectives, and would provide hydrologic benefits similar to Option A.

**Option D**

Option D would meet wildlife connectivity objectives. The combination of a wildlife overpasses with nearby wildlife underpasses and an aquatic linkage would be the most effective solution for providing terrestrial and aquatic species movement in this CEA.

This option meets hydrologic connectivity objectives, and would provide hydrologic benefits similar to Option A.

See Exhibit 3.15-3 at the end of this section for a detailed comparison of the options.

**Recommended Restoration Measures**

If approval cannot be obtained for replacing the bridges at the Kachess River (which are functional from a transportation perspective) as specified in Option D, we recommend attempting to retrofit wildlife connectivity benches under the widened bridges. The objective would be to make these benches as broad as possible by excavating existing fill supporting the abutments and replacing it with vertical retaining walls. This measure is desirable because Kachess Lake and Kachess River naturally funnel wildlife toward this section of the highway, and any improvements in opportunities for crossing would reduce roadkill.

**Performance Standards**

All performance standards apply to the Kachess River/Lake Easton CEA (see Attachment 3).
Are there other potential restoration opportunities?

- Create connectivity benches under the Kachess River bridge by excavating existing fill supporting the abutments and replacing it with vertical retaining walls. This is desirable because Kachess Lake and the Kachess River naturally funnel wildlife toward this section of the highway, and any improvements in opportunities for crossing would reduce roadkill.

- Enhance riparian vegetation along the Kachess River. This would likely require working with USBR to ensure that operations of the Kachess Reservoir are consistent with the development and maintenance of a restored riparian area.

- Restore wetlands in the Lake Easton area.
### Kachess River Options Comparison Table
Exhibit 3.15-3

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wildlife Connectivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Location of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the location of the crossing structure in this CEA fit with the topography and natural movement patterns within a “linkage area”? Does the location coincide with the findings of Singleton and Lehmkuhl (2000)?</td>
<td>A</td>
<td>Yes</td>
<td>This option would provide access to the Silver Creek roadless area. Singleton and Lehmkuhl (2000) state this CEA is a moderate permeability area. In addition, snow tracking and remote cameras indicate this is a high use area for wildlife.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td><strong>Attributes of Crossing Structure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the structure in this CEA provide opportunities to buffer traffic disturbances from noise and light?</td>
<td>A</td>
<td>No</td>
<td>The county road obstructs connectivity.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>The overcrossing can be designed to screen out noise and light using earth berms or walls.</td>
</tr>
<tr>
<td>Are height, width, and length of the structure in this CEA adequate to meet the needs of large carnivores and ungulates? Will the connectivity structure allow animals to move when snow is present?</td>
<td>A</td>
<td>Yes</td>
<td>Widening the bridge over the county road would improve crossing opportunities for high-mobility species. High clearance would be adequate to deal with low snow loads at this drier end of the corridor.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Traffic would be a deterrent to some species.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option B.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>The overcrossing structure provides the greatest opportunity for year-round use by the largest number of species.</td>
</tr>
<tr>
<td>Does the structure in the CEA allow for the establishment of habitat elements (within/on the structure) to increase the probability of low-mobility species movement (including native soils, vegetation growth, diversity, and ecosystem processes)?</td>
<td>A</td>
<td>Yes</td>
<td>Height would facilitate vegetation development within structure. No special soil type present. Amphibians, reptiles, and the small mammal assemblage associated with drier forest types are focal groups.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>Size and shape are large enough to allow some low-mobility species to pass. Lack of habitat conditions will exclude others (e.g., salamanders, frogs, shrews, &quot;corridor dwellers&quot;). Traffic a deterrent to use and crossing success.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Same as Option B.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>The overcrossing can support the establishment of good habitat components on the crossing itself that would benefit...</td>
</tr>
</tbody>
</table>
### Kachess River Options Comparison Table

**Exhibit 3.15-3**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are populations of species associated with different habitat types in this CEA connected?</td>
<td>A</td>
<td>Yes</td>
<td>Terrestrial habitat is the primary focus of the county road bridge. The Kachess bridge would link aquatic habitat, but riparian habitat is not present (bare soil beneath bridges). Like Easton Hill, this is moist grand fir vegetation type.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>This option would not link terrestrial habitat (only pavement within the structure).</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Same as Option B.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>The overcrossing structures provide the greatest opportunity for year-round use by the largest number of species, including low-mobility species (except those associated with aquatic habitats).</td>
</tr>
<tr>
<td>Can human activities in this CEA be managed for compatibility with the function of the crossing structures?</td>
<td>A</td>
<td>No</td>
<td>Vehicle traffic on the county road is low now, but may increase with increasing private development to the south. There is little human use to the west.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>No</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>The overcrossing structures would be located away from human activities.</td>
</tr>
<tr>
<td>Is the adjacent land owned by public parties?</td>
<td>A</td>
<td>Yes</td>
<td>There is public land almost entirely to the north and below Kachess Dam (northeast); private development to the east and southwest; and state land, including Yakima wildlife area to the south. There are some private parcels to the south and west, but mostly low-density housing. The Cascades Conservation Partnership is purchasing some private lands.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Yes, the overcrossing structures would be located on public lands.</td>
</tr>
</tbody>
</table>

### Hydrologic Connectivity

<table>
<thead>
<tr>
<th>Does this option provide for stream crossings that meet WDFW stream simulation specifications and provide for the movement of aquatic organisms, wood, sediment, and debris necessary for stream channel function, aquatic species viability, and proper functioning riparian and aquatic habitats?</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Yes</td>
<td>This option’s widened bridge would maintain current channel functions.</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Does this option accommodate stream channel migration on unconfined floodplains and alluvial fans?</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>N/A</td>
<td>Natural channel migration is limited by upstream and downstream channel modifications and reservoir operations.</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>N/A</td>
<td>Same as Option A.</td>
<td></td>
</tr>
</tbody>
</table>
### Kachess River Options Comparison Table

**Exhibit 3.15-3**

<table>
<thead>
<tr>
<th>Connectivity Structure Evaluation Questions</th>
<th>Option</th>
<th>Meets Standard?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Does this option avoid impacts on wetland hydroperiods?</td>
<td>D</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Yes</td>
<td>The wetland hydroperiods in this CEA are governed by Lake Easton backwater and would not be altered by widening the Kachess River bridge.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Does this option provide continuous wetland flow through the I-90 roadbed in locations where there is potential to link high value wetlands?</td>
<td>A</td>
<td>N/A</td>
<td>Existing wetlands are primarily fed by Lake Easton backwater.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Does this option restore natural surface and subsurface flow paths through the I-90 roadbed?</td>
<td>A</td>
<td>N/A</td>
<td>Flow paths in this area are primarily confined to the altered Kachess River channel and Lake Easton shoreline.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>N/A</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Does this option minimize new fill and take advantage of opportunities to remove historical fill from floodplains, flood-prone areas, and shallow groundwater and emergence zones?</td>
<td>A</td>
<td>Yes</td>
<td>This option would limit highway fill to the existing highway footprint and upland embankments, and would avoid filling floodplain areas.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td>Does this option avoid and minimize soil compaction and detrimental soil disturbance on floodplains, wetland soils, seepage zones, and groundwater recharge areas?</td>
<td>A</td>
<td>Yes</td>
<td>This option would limit highway fill to the existing highway footprint and upland embankments, and would avoid filling wetland areas on the west bank.</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Yes</td>
<td>Same as Option A.</td>
</tr>
</tbody>
</table>
CHAPTER 4

Project-wide Evaluation
Introduction

In this chapter we describe our evaluation of ecological connectivity at the scale of the entire project. Having identified the design options and management strategies that meet ecological connectivity objectives at the scale of each CEA (Chapter 3), we will now analyze whether the combination of recommended mitigation measures across all CEAs will meet our broad, project-wide connectivity objectives (see page 1-8 and Attachment 3).

This chapter describes both our methods and the results of our evaluation of project-wide connectivity. We conclude our project-scale evaluation with recommendations that apply at the project-wide scale, a discussion of priority information needs, and future planning needs.

Why did we evaluate ecological connectivity at the scale of the entire project?

One key premise underlying our project-wide evaluation is that each CEA represents an opportunity to link a unique assemblage of species and/or habitats. What this means at the project-wide scale is that connections for wildlife and hydrology must be distributed in a way that accommodates the different linkage zones and habitat types found across the landscape; a lack of connectivity in one linkage zone cannot be compensated for by additional connectivity structures in other zones.

Although meeting connectivity objectives at each CEA is a necessary component of meeting project-wide objectives, we feel it may not be sufficient to sustain linkages between populations of species and ecological processes at the landscape scale. This opinion derives from several factors, including:

- CEAs occupy a small proportion of the entire 15-mile project area.
- The project boundaries place constraints on linking some habitat types.
- Most CEAs are located in riparian areas.
- Constructability issues limit the distribution of large crossing structures.

Thus, a project-wide analysis was necessary to determine if these factors might prevent attainment of connectivity objectives even though a functional option was available for each CEA.

How did we evaluate project-wide connectivity?

We evaluated connectivity at this larger scale following a process parallel to the one we used for our evaluations at the CEA scale. In Chapter 3 we described our
approach to CEA-scale evaluation. Briefly, we used existing literature to generate a set of performance standards relevant to the effectiveness of proposed designs. We translated these performance standards into questions, which we asked about each design option in light of CEA-specific connectivity objectives. The fit between the performance standards met by a design option and CEA-specific objectives determined the sufficiency of that option.

To evaluate project-wide connectivity, we used a similar approach. Early in the process of working on this project, we developed broad objectives that would help us evaluate whether project designs would meet ecological connectivity goals (see page 1-8 and Attachment 3). These objectives are project-wide analogs of CEA-scale performance standards. We translated these project-wide objectives into a set of three questions which we used to probe project-wide connectivity. The project-wide questions were:

1. Are aquatic and terrestrial habitats sufficiently linked to function properly for the species they support? Habitats of particular importance include old-growth forests, upland forests, wetlands, riparian habitats, streams, and unique habitats (e.g., talus).

2. Are connections provided for hydrologic processes sufficient to allow for proper function of stream channels, riparian areas, floodplains, wetland flow paths and hydroperiods, and groundwater-surface water interactions?

3. Will highway-related mortality and impediments to movement be reduced sufficiently to provide a moderate to high probability of sustaining local and regional populations of all species and to reduce risks associated with demographic isolation and limited genetic variability?

These questions were designed to address different components of our desired future condition for landscape-scale connectivity. Our approach to answering these questions was to build on the results of our CEA-specific evaluations by considering areas between CEAs and the degree to which all habitats, species, and ecological processes would be linked across the landscape spanned by the project.

**Are wildlife and hydrologic connectivity objectives met at the project-wide scale?**

We found that our project-wide connectivity objectives would be met by combining design options that meet CEA-specific objectives with:

- The installation of small and medium crossing structures at upland sites at regular intervals as constructability allows, and

- Implementation of recommended performance standards to reduce highway impacts outside the CEAs.
We present our rationale for this finding in our responses to the project-wide questions.

**Are aquatic and terrestrial habitats sufficiently linked to function properly for the species they support?**

Aquatic, wetland, and riparian habitats will be well connected in every linkage zone. Crossing structures at Price, Noble, and Bonnie creeks and a smaller structure at the unnamed creek east of Toll Creek will link the best remnant patches of old-growth forest habitat. Although talus habitats are targeted at only one CEA (Hudson Creek), it may be possible to add talus to large structures in other linkage zones to improve connectivity for talus-associated species. The most apparent deficiency at the project-wide scale is that upland habitats are not adequately connected, especially the mountain hemlock-subalpine fir habitat type.

Except for Easton Hill, CEAs are all located in riparian areas. Option D at Price-Noble and Option D at Kachess River increase the potential connections between upland habitats. At Price-Noble, however, there are other options that meet connectivity objectives and may be selected for inclusion in the preferred alternative for the project. The Kachess River overcrossing is within about one mile of the Easton Hill CEA, meaning that upland crossing opportunities are not well distributed. Over-reliance on riparian areas may not accommodate crossing use by species that typically occupy upland habitats or prefer upland habitats for dispersal (e.g., Canada lynx). We believe this issue could be addressed in part by building additional upland crossing structures at intervals of about 820 feet, where constructible and feasible (see *What are our key project-wide recommendations*? below).

Proposed designs for the Gold Creek crossing structure effectively link floodplain habitat, but not forested upland habitat in this vegetation type. Thus, species associated with these habitats, particularly low-mobility species, do not have access to crossing opportunities unless they move into riparian floodplain habitat—a habitat they may find less suitable.

We considered several potential approaches to address linkage of subalpine fir-mountain hemlock habitats. The project team was unable to design a connectivity structure to link this habitat due to both inflexible constraints imposed by existing infrastructure and the location of the western project terminus very near to the location where the subalpine fir-mountain hemlock vegetation association intersects the highway. This narrow overlap between the project and the habitat type limited design options. The most promising potential solutions involved construction of crossing structures outside the project area to the west. Because these locations are outside the project area, construction would most likely need to occur as part of a separate project. Furthermore, preliminary design and cost analysis suggested these structures would be expensive and would present serious design challenges. These constraints precluded effective linkage of this habitat type within the project area. Thus, this project-wide objective is not fully met.
Because the project functionally links nearly all other habitat types adjacent to the highway, we suspect this shortcoming is minor relative to the scope of project-wide improvements. However, we do not know the ecological consequences of not fully linking this habitat. We suggest that further investigation of the demographic characteristics of low-mobility species associated with subalpine fir-mountain hemlock habitats in the project area is warranted to better understand the status and trends of local populations. We also encourage the development of future projects that provide connectivity structures within this habitat type.

**Are connections provided for hydrologic processes?**

Yes. Because we focused our efforts on providing ecological connectivity at stream crossings, hydrologic connectivity needs are predominantly met within CEAs. Consequently, our project-wide evaluation revealed no significant gaps in hydrologic connectivity that needed to be addressed. Under certain options, stream crossing structures on unconfined streams like Gold Creek, Price Creek, Noble Creek, Bonnie Creek, and Swamp Creek will restore stream channels, riparian areas, and floodplains through the highway. Improved culverts at Wolfe Creek, Resort Creek, Townsend Creek, Toll Creek, Cedar Creek, and Telephone Creek will provide the flow capacity, debris passage, and aquatic linkages needed for natural channel functions upstream and downstream of the highway. Opportunities at the Kachess River crossing are limited because of upstream and downstream reservoir operations, but the crossing structure will provide adequate aquatic linkages. We have also designated HCZs where special structures would maintain, enhance, or restore natural flow paths between wetlands, seepage zones, and shallow aquifers at the Price and Noble Creeks, Swamp Creek, Hudson Creek, and Easton Hill CEAs.

Stream crossing structures under certain options at Gold Creek, Bonnie Creek, Swamp Creek, and the unnamed creek in the Toll Creek CEA will restore wetland habitats under the highway and connect wetlands in floodplain and riparian areas. HCZs at the Price and Noble Creeks, Swamp Creek, Hudson Creek, and Easton Hill CEAs will restore flow paths between existing and historical wetlands that are now disconnected by the highway.

**Will highway-related mortality and impediments to movement be reduced sufficiently to provide a moderate to high probability of sustaining local and regional populations?**

Yes. Similar to our response to the first question about linking habitats, we also found that combining CEA design options that meet connectivity objectives with implementing project-wide performance standards will substantially reduce mortality and facilitate dispersal across the highway.

Relative to the existing highway, constructing design options that meet connectivity objectives would lead to profound improvements in the potential for wildlife to cross the highway successfully. Across the project area, nearly three-
quarters of a mile of crossing structures are proposed. Crossing structures have been located in sites known or suspected to be important for wildlife movement. Most designs accommodate both high- and low-mobility species. An array of performance standards will ensure that crossing structures have the physical attributes and management approaches that enhance their performance. Overall, we are confident that implementing the options we evaluated as likely to meet connectivity objectives will increase the probability of sustaining local and regional populations. This includes populations of species currently common in the project corridor (e.g., ungulates), species that are currently rare and may increase in abundance (e.g., gray wolf and grizzly bear), and species that have been extirpated (e.g., fisher) and may re-colonize or be re-introduced to the area during the design life of the proposed project. We also recognize that a comprehensive, long-term monitoring program will be necessary to provide a definitive answer to this question.

Although we are confident this objective is met project-wide, the 3.5-mile stretch of highway between Toll Creek and Hudson Creek is problematic. This area includes the steep southern slope of Amabalis Mountain (we refer to the CEAs at Cedar, Telephone, and Hudson creeks as the Amabalis Mountain CEAs). This set of CEAs forms a natural grouping because of constructability challenges associated with locating crossing structures on very steep slopes.

I-90 is cut into the base of Amabalis Mountain, resulting in steep cut slopes on the north side and steep fill embankments on the south side of the highway (Singleton and Lehmkuhl 2000). Proposed widening of the highway may lead to even higher cut slopes and fills. The steep slope of the terrain limits the amount of clearance available for crossing structures under westbound lanes. Overcrossings are not possible because the ground surface south of the highway slopes away too rapidly. Consequently, in this stretch, constructability constraints will result in a 3.5-mile stretch of the project that does not have any crossing structures suitable for large, high-mobility, terrestrial species.

The Cedar and Telephone Creek CEAs are located within this 3.5-mile stretch of highway. In our evaluations of the single designs proposed for Cedar and Telephone creeks, we found these structures would not meet connectivity objectives. We were then confronted with the question, does inability to meet connectivity objectives at these two CEAs constitute a large enough shortcoming that it compromises project-wide objectives?

To address this question we evaluated the relative importance of these CEAs to ecological connectivity in the overall landscape crossed by the project. We relied on previous monitoring results for this evaluation. Roadkill information reviewed by Singleton and Lehmkuhl (2000) indicated a gap (i.e., very low numbers) between MP 64 and MP 67, corresponding to the area with no adequate connectivity design options. These monitoring results reflect the impermeability of this area to ungulates. Snow tracking and camera surveys, however, revealed that carnivores (coyote, bobcat, and black bear) are regularly detected in this area. Studies at other locations have suggested that coyote, bobcat, and black
bear are willing to use crossing structures with limited openness. Landscape linkage models also indicated that the area adjacent to Easton Hill was a location where animals were likely to encounter the highway (Singleton and Lehmkuhl 2000). These models were strongly influenced by historic patterns of timber harvest (Singleton and Lehmkuhl 2000). These harvest patterns may not reflect future patterns, given that much of the private timberland in the project area has been transferred to public ownership, and National Forest management in the area emphasizes development of late-successional habitat. A reforested landscape could yield different patterns of animal movement; rather than use steep terrain because it is the only forested habitat available, animals will use gentler terrain as forest regrowth proceeds.

Based on this information, our opinion is that this 3.5-mile stretch of the highway is not a focal point of landscape-scale connectivity, and that its relative importance may decline as previously cut forests grow back in other areas. Installing small connectivity structures in this stretch of highway, as constructability opportunities permit, is likely to adequately address connectivity needs. The combination of (1) a relative lack of large ungulates, (2) presence of species known to use less open crossing structures, and (3) difficult access to the highway in this area due to steep terrain suggests that small connectivity structures may be the best solution for this difficult section of the project.

As discussed in our response to the first project-wide evaluation question, the western boundary of the proposed project limits opportunities to link species associated with subalpine fir-mountain hemlock habitat, especially low-mobility species. We suggest investigating the degree of demographic isolation of low-mobility species associated with this habitat as a first step toward understanding how best to manage this situation.

What are the MDT’s key project-wide recommendations?

Across the project, the MDT recommends:

- Encouraging wildlife use of crossing structures. Achieving this objective will require developing an integrated strategy, implemented project-wide, that (1) reduces wildlife avoidance responses to the highway within CEAs, (2) guides wildlife to crossing structures, and (3) prevents wildlife access to the road surface. A variety of design features could be used in this strategy, including vertical retaining walls in place of side slopes for elevated sections of the roadway, guide fencing tied to topographic barriers, boulder fields, and traffic noise and light reduction measures near crossing structures. Available information suggests that crossing structure performance benefits considerably from measures that encourage wildlife to get close enough to structures to use them.

- Minimizing habitat impacts associated with fill/slopes and fencing. Wildlife exclusion and guide fencing associated with highway embankments reduce: (1) habitat by increasing the footprint of the highway; (2) habitat quality by
providing opportunities for invasive weeds to become established and spread along side slopes; and (3) access to habitat features; and are costly to install and maintain. Vertical retaining walls address all of the adverse consequences of fencing and embankments listed above and are a particularly attractive design solution. Vertical retaining walls may also provide visual benefits by reducing the need for visually intrusive fences.

- Maximizing the openness of wildlife undercrossings. Available information indicates that increasing openness is likely to increase the diversity of species willing to use a structure. Given the multi-species, ecosystem-wide objective of this project, maximizing openness for all sizes of crossing structures (small, medium, and large) will likely contribute to improved performance. Maximizing openness will also provide better habitat connections by increasing opportunities for plant development and placement of natural structural complexity within crossing structures. A wide range of design tools is available for maximizing undercrossing openness, including vertical retaining walls with bridge abutments, flat slab bridges to reduce girder depth, and other measures. We encourage creatively using all available engineering and architectural tools that can contribute to maximizing crossing structure openness.

- Minimizing noxious weed occurrence and herbicide treatment. This objective can be achieved through highway design that minimizes fill slopes and uses innovative approaches to encourage only native plant species adjacent to the highway. Providing high-quality habitat adjacent to the highway minimizes the risk of colonization and spreading of noxious weeds. Fill slopes create an unnatural environment in which noxious weeds are able to quickly colonize and then spread into more pristine habitats. Herbicides are typically the only effective treatment to control weeds. However, the use of herbicides is detrimental to native plants and animals and to water quality. Vertical retaining walls are a particularly attractive design solution because they reduce the need for fill slopes and the negative consequences of herbicide use. Vertical walls also have the added benefit of reducing the highway “footprint,” loss of wetlands, and the need for other animal exclusion methods. In areas where vertical retaining walls are not feasible, other measures should be used to ensure noxious weed and herbicide treatment objectives are met.

- Bundling of lanes (keeping them together rather than separated by a central median). Bundling lanes achieves two primary ecological connectivity objectives by: (1) decreasing the highway “footprint” and reducing the loss of habitat and (2) shortening the length of the crossing structures from the wildlife perspective and increasing structure openness (Clevenger 2005). Available information suggests that wildlife generally prefer shorter crossings. We recognize that other requirements of highway alignment, stormwater treatment, safety issues, visual interest, and maintenance operations may constrain opportunities for bundling lanes. We also recognize that in some locations where the median is very wide (e.g., Easton Hill), some objectives
achieved in the bundling of lanes can be accomplished with this wide separation of travel lanes, effectively resulting in two separate short crossings. In the absence of such a wide median, bundling lanes, particularly within the CEAs, would produce similar results.

- Installing small and medium crossing structures at a frequency of about six per mile in upland project areas outside of CEAs. This frequency is a guideline, and the distances between these structures are sure to vary appreciably around an average of about 820 feet as a result of optimizing structure locations and engineering feasibility. Previous monitoring in the I-90 corridor found that such structures may provide important and relatively secure movement routes for small mammals (Singleton and Lehmkuhl 2000). Additional preconstruction monitoring will be critical for finding the best locations for these structures. Maintaining habitat structure near the ends of these small structures may encourage use by small mammals (Singleton and Lehmkuhl 2000).

- Monitoring. We believe that the value of all investments in connectivity in this project will be enhanced tremendously if they are matched with a robust and coordinated research and monitoring program. In Chapter 2, we describe the need for, and basic framework of, a monitoring plan. But a monitoring program adequate to the task will require an interdisciplinary team with expertise in monitoring design to craft a set of questions that meet both scientific and management information needs. These questions would then need to be matched with an efficient sampling protocol.

Time is of the essence in developing this monitoring program, especially the critical pre-construction component. The design of this monitoring program should proceed parallel to the refinement of highway structural designs. As a first step, we recommend hiring a research and monitoring coordinator, ideally a scientist recognized in the field of road ecology. This coordinator could be responsible for leading the development of a monitoring strategy that ensures questions associated with both crossing/connectivity structure effectiveness and transportation safety and efficiency are addressed. This coordinator should also be responsible for collaborating with other scientists and non-government agencies in pursuing funds.

We are concerned that the exceptional opportunity for learning from the proposed project may not be fully realized if independent research and monitoring studies are undertaken in a piecemeal fashion. Although each of these independent studies may be of impeccable quality, without concerted efforts to have each study contribute to a coordinated program, key issues may be missed. Because this highway project is likely to be implemented in phases, a coordinated monitoring program will also increase the chances that lessons learned in early phases of construction will be applied to subsequent phases.
Establishing a multi-agency Ecological Connectivity Implementation Team to coordinate with the project engineering design team to refine roadway designs. This coordinated approach holds the greatest promise for making our optimistic evaluations of connectivity structure performance a reality.

**What information do we need to improve project planning and implementation?**

During our evaluation, we identified the following critical information needs:

- Additional baseline information is needed before project implementation begins. Baseline information regarding ecological connectivity is limited primarily to Singleton and Lehmkuhl (2000) and aquatic (WSDOT 2002b), terrestrial (WSDOT 2004a), and hydrology (Null and McQueary 2004; WSDOT 2005b) discipline reports for the I 90 Snoqualmie Pass East Project. New baseline studies are needed to provide information about low-mobility species. In particular, global position system (GPS)/radiotelemetry studies of movements by individuals and analyses of population genetic structure could provide the most useful baseline information against which to compare the results of similar surveys following project completion (for example, continued funding of the WDFW mountain lion radiotelemetry project, or tracking other big game animals). More specific information on the geomorphology of unconfined streams like Gold, Price, Noble, and Swamp creeks is needed to design dynamically stable channels beneath crossing structures. Groundwater flow information is needed to refine the location and designs of structures in HCZs.

- Groundwater monitoring wells have been drilled in hydrologically active locations across the project area. Further analysis of the information provided by these wells is needed. These preliminary analyses could improve understanding of groundwater processes and could help to determine if additional wells and other information are needed to help refine design options in ways that improve hydrologic connectivity.

- Another useful study would be to reevaluate landscape permeability in the project area. Existing landscape linkage models for the project area were strongly influenced by (1) historic timber harvest patterns and road density, and (2) residential development (Singleton and Lehmkuhl 2000). Much of the private land in the corridor now has been transferred to public ownership, and management direction for National Forest land emphasizes development of late-successional habitat. Linkage modeling could be used to investigate where animal movement is likely to occur in a reforested landscape with reduced road density scenarios. This information could be useful in refining our ecological connectivity strategy over the course of project implementation.
What issues need to be addressed in subsequent stages of planning?

Our primary task was to biologically evaluate the likely performance of the proposed project-wide approach to providing ecological connectivity. As we worked on this task we repeatedly encountered technical, regulatory, and policy issues that could affect the success of connectivity efforts, but these issues were beyond our expertise or our scope of work. Many of these issues were related to mitigation requirements and management of lands adjacent to the highway right-of-way. We list these issues here in an effort to encourage WSDOT and FHWA to continue to work on developing a comprehensive and integrated connectivity and mitigation strategy.

- **Wetland Mitigation**
  - Identify restoration opportunities (e,g., Price/Noble Sno-park).
  - Identify replacement wetlands in the project area.

- **Hydrologic Monitoring**
  - Continue to collect and analyze groundwater data at HCZs to identify subsurface flow patterns.
  - Refine mapping of small streams and seepage zones.
  - Develop a conceptual model of hydrologic processes in each CEA using topographic, geologic and soil maps, and ground and surface water elevations.

- **Water quality**
  - Stormwater treatment. A conceptual plan for stormwater management has been developed, but potential conflicts may arise in the CEAs, particularly with HCZs. Resolving these conflicts in ways that are compatible with connectivity objectives will require ongoing collaboration between design engineers, hydrologists, and biologists. Solutions are likely to be site-specific and will be best developed as site-specific designs are refined.
  - Herbicides. Inherent difficulties exist in trying to balance the adverse effects of noxious weeds and the adverse effects of chemicals used to control these weeds. Finding this balance is beyond the scope of this recommendation package. The U.S. Forest Service is currently developing regional and sub-regional standards for herbicide use. These efforts may be a useful starting point for developing a project-specific strategy that incorporates consideration of connectivity issues.
  - Traction sand, anti-icers, and de-icers

- **Crossing structure effectiveness in winter**
  - An operations plan for snow removal to minimize adverse effects on crossing opportunities
  - Fencing maintenance
Management coordination
- Consistency of the design and operation of the highway facility with National Forest plans and strategies
- Consistency of National Forest land management with investments in crossing structures
- Ensuring integrity of wildlife movement corridors by acquiring private lands that, if developed, could compromise the function of crossing structures

Prolonged implementation schedule
- Consistency with the original objectives outlined here, while maintaining flexibility to respond to new knowledge

Enhancement opportunities
- Wildlife crossings off-site. Pursue funding opportunities for connectivity enhancement outside the project area in Pacific silver fir-mountain hemlock habitats (e.g., Hyak).
- Identification and purchase of mitigation parcels adjacent to I-90 close to CEAs or critical habitats.
CHAPTER 5

Findings and Recommended Options
Chapter Five  

Findings and Recommended Options

Introduction

In this chapter we compile our findings about connectivity at two different scales: the site-specific scale of individual CEAs (Chapter 3) and the broader landscape scale of the entire project (Chapter 4). We begin with a summary of our findings about whether different design options meet connectivity objectives at the scale of individual CEAs, and offer our recommendations about which options we prefer when more than one option meets objectives. We conclude with a brief summary of our findings about project-wide connectivity.

What are the results of the individual CEA design option evaluations?

The MDT evaluated the 15 CEAs to determine if proposed design options would meet ecological connectivity objectives as defined by the MDT in support of the Purpose and Need for Action chapter of the I-90 Snoqualmie Pass East Draft Environmental Impact Statement. For more information about the scope of the MDT’s evaluation, see What was the methodology and approach used for preparing this package? in Chapter 1 of this recommendation package.

We evaluated each CEA against a unique set of objectives because each CEA addresses different habitats and ecological functions, with an array of unique species. Our evaluation was conducted through a series of questions based on the performance standards. The answers to these questions, as well as additional management recommendations and off-site restoration opportunities for each CEA, are provided in Chapter 3.

Exhibit 5-1 summarizes our findings in a graphical format. In this exhibit we summarize CEA-specific objectives by indicating the level of emphasis we placed on a few key types of functional objectives relevant to species mobility groups and hydrologic processes. Increasing numbers of dots indicate increasing emphasis. Below the map of the project area we indicate those design options that meet the objectives emphasized at each CEA. Among the options that meet connectivity objectives, we rank our preferred options.

To meet the overall connectivity goals in the project area it is necessary to meet the objectives at each of the CEAs. Of the CEAs with multiple design options, the following options were determined to meet the ecological objectives:

- Gold Creek (Option A, B, and D)
- Resort Creek (three separate options, each associated with a different alignment)
- Price and Noble Creeks (Option A, B, and D)
- Bonnie Creek (Option A)
- Swamp Creek (Options A and B)
- Toll Creek (Option A or B, which are identical)
- Hudson Creek (Option A)
- Easton Hill (Options A, B, and C)
- Kachess River/Lake Easton (Option D)

Except for the Telephone and Cedar Creek CEAs, we found that the remaining CEAs where only one design option was developed would meet CEA-specific connectivity objectives. Please see the subsections in Chapter 3 entitled *How will the options perform?* for each CEA and the associated option comparison tables for details about the MDT’s findings regarding each design option.

### What is our recommended package of design options?

The MDT found that only one design option met the ecological connectivity objectives at the Resort Creek, Bonnie Creek, Toll Creek, Hudson Creek, and Kachess River/Lake Easton CEAs. Several options met the ecological connectivity objectives at Gold Creek, Price and Noble Creeks, Swamp Creek, and Easton Hill CEAs. At these CEAs, we ranked the options in order from most to least preferred based on our assessment of the degree to which they will meet ecological connectivity objectives. Our rankings of options are shown below and in Exhibit 5-1.

<table>
<thead>
<tr>
<th>CEA</th>
<th>1st Choice</th>
<th>2nd Choice</th>
<th>3rd Choice</th>
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<tbody>
<tr>
<td>Gold Creek</td>
<td>A</td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td>Price and Noble Creeks</td>
<td>D</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Swamp Creek</td>
<td>B</td>
<td>A</td>
<td>–</td>
</tr>
<tr>
<td>Easton Hill</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

At the Gold Creek CEA we ranked the options in this order because:

- Option A places the wildlife crossing bridge to the west, close to subalpine fir-mountain hemlock habitat at the edge of the floodplain where many terrestrial species will encounter it. The long span over Gold Creek provides for channel migration over most of the historic floodplain.

- Option B wildlife connectivity is further removed from subalpine fir-mountain hemlock habitat and would require wildlife traveling along the edge of the floodplain to move out toward the stream channel to find the crossing. This may be an impediment to use, especially by low-mobility species. Hydrologic performance is indistinguishable from Option A.
Summary of CEA Options

- **North-South Linkage Zones**: HCZ = Hydrologic Connectivity Zone

**ASSUMPTIONS BEHIND HYDROLOGY RATINGS**: Stream channel process, for CEAs with unconfined floodplains and dynamic migrating streams. For CEAs where focus is on fish and habitat passage, where only minor streams occur. Blank means no streams. Wetland flow paths, indicates high value wetland resources and/or subsurface flow paths at the CEA. **** indicates some wetlands, relatively low value or less extensive. Blank indicates wetland and subsurface flow are relatively minor.

- At the Resort Creek CEA, different highway alternatives are linked to different design options (three separate options).
- Resort Creek Alignments 3 and 4: multiple culverts with combined width of 100 feet. At least one culvert to provide 12-foot clearance.

**Level of Emphasis**: Strong emphasis, Moderate emphasis, Low emphasis, Little or no emphasis

**Option Recommendation Ranking**: three stars = highest

**Option meets connectivity objectives**

**Option does not meet connectivity objectives**

### MDT Recommendation Ranking

<table>
<thead>
<tr>
<th>Option</th>
<th>Milepost</th>
<th>Northeast Linkage</th>
<th>Eastern Linkage</th>
<th>Hydrologic Connectivity</th>
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<td>55.1</td>
<td>120' bridge</td>
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<tr>
<td>D</td>
<td>70.3</td>
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<td>1 HCZ</td>
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</tbody>
</table>

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**Legend**

-

- [Image 688x1002]
- Option D provides similar wildlife connectivity as Option A, but provides only a minimum acceptable level of hydrologic connectivity.

At the Price and Noble Creeks CEA, wildlife connectivity was found to vary more widely with different options than hydrologic connectivity, thus wildlife connectivity was weighted more heavily. We ranked the options in this order because:

- Option D provides the greatest potential for accommodating the crossing preferences of all species known or expected in the CEA by combining paired undercrossings with an overcrossing (unlimited openness). Sno-park removal reduces the potential for disturbance due to human activity. The hydrologic performance of Option D is the least preferred of the three options.

- Option A provides nearly double the openness of Option B, providing conditions favorable to use by both high- and low-mobility species. Long bridges over hydrologic features provide the highest level of restored hydrologic connectivity.

- Option B provides limited vertical clearance for the multi-span bridge at the creeks, diminishing likely performance for both high- and low-mobility species.

At the Swamp Lake CEA, we ranked the two options that met ecological connectivity objectives in this order because:

- Option B provides better habitat linkages for high-mobility species and better separation from a potential source of human disturbance. The bridges also provide greater height clearances than Option A. This option provides an additional HCZ and 120-foot bridge to improve connectivity between high-value wetlands west of Swamp Creek. The Option B bridge over Swamp Creek removes less wetland fill than Option A, but combines with an HCZ to provide a similar level of wetland flow and channel process restoration.

- Option A provides greater linkage of wetland habitats and associated species. However, this option provides less linkage for large high-mobility species due to lower height clearances and less linkage in areas away from human disturbance. A larger bridge over Swamp Creek provides less hydrologic connectivity between wetlands west of Swamp Creek, but provides a longer span over the Swamp Creek floodplain that removes more wetland fill.

At the Easton Hill CEA, we found that the differences among options in their expected performance were relatively subtle compared to other CEAs with multiple options that met connectivity objectives. We ranked the options in this order because:

- Option A bridges a pathway that currently receives a high level of ungulate use. Bridging this accustomed route would likely promote use of the crossing structure. This option facilitates east-west linkage to the Kachess River/Lake Easton CEA (Option D) if the entire median could be fenced (MDT
recommendation). This option provides the greatest hydrologic connectivity for the designated Wetland AM.

- Option B provides unlimited openness (overcrossing) and does so over lanes that are relatively tightly bundled, shortening the crossing. The overcrossing provides opportunities for buffering noise and light disturbance. This option aligns well with ridgeline travel paths, but field surveys suggest that the current level of use may not be as high as the Option A pathway. Linkage to the Kachess River/Lake Easton CEA is reduced. Wetland AM is connected via an HCZ.

- Option C uses an “under-over” combination of crossing structures with a wide median—an untested approach.

**What are the results of the project-wide evaluation?**

Recognizing that CEA-scale connectivity was necessary, but not sufficient to provide project-wide connectivity, we went on to evaluate project-wide connectivity.

We found that project-wide wildlife connectivity objectives are likely to be met by combining design options at CEAs that meet CEA-specific objectives with:

- Installation of small crossing structures at upland sites as constructability allows, and
- Implementation of performance standards to reduce highway impacts outside of the CEAs.

We expect this combination of features to result in profound improvements in ecological connectivity compared to the existing condition.

The issues that challenged us most about project-scale connectivity were lack of connections for the subalpine fir-mountain hemlock habitats and lack of connectivity for large, high-mobility species in the 3.5-mile stretch of highway from Toll Creek to Hudson Creek (the Amabalis Mountain CEAs). We found that both of these issues did not change our professional judgment that project-wide connectivity objectives are met.

From a hydrologic perspective, project-wide connectivity needs are predominantly met by design options that meet objectives within CEAs. This outcome reflects our approach of focusing efforts at providing ecological connectivity at stream crossings. Consequently, our project-wide evaluation revealed no significant gaps in hydrologic connectivity that needed to be addressed.
Chapter Six

Chapter 1


Chapter 2


Zak, J.C., P.R. Fresquez, and S. Visser. 1990. Soil microbial processes and dynamics: their importance to effective reclamation. In: Evaluating reclamation


Chapter 3


Pierce, R.J. 2005. Personal communication.


**Chapter 4**


CHAPTER 7

List of Preparers
## List of Preparers

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Contribution</th>
<th>Education</th>
<th>Certifications, Licenses, and Professional Organizations</th>
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<td><strong>Mitigation Development Team</strong></td>
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<tr>
<td>William Ehinger</td>
<td>U.S. Forest Service</td>
<td>Hydrologist</td>
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<td>Patty Garvey-Darda</td>
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<tr>
<td>Richard Gersib</td>
<td>Washington State Department of Transportation</td>
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<td>B.S., Wildlife Management</td>
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<td>Karl Halupka</td>
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<td>Ph.D., Ecology</td>
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<td>Pat McQueary</td>
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<td>B.S., Marine Biology</td>
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<td>M.S., Marine Biology</td>
<td>M.E.S., Environmental Communities Emphasis</td>
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<td>William Meyer</td>
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<td>Rob Schanz, P.E.</td>
<td>Washington State Department of Transportation</td>
<td>Hydrologist</td>
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<td>M.S., Civil Engineering</td>
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<td></td>
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<td>Licensed Civil Engineer – Washington and California</td>
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<td>Paul Wagner</td>
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<td>Kim Vaughn</td>
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<td>MDT Team Leader/Engineer</td>
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<td>Myria Foisy</td>
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<td>Katie Eirich</td>
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<td>Graphics/Engineer</td>
<td>B.S., Civil Engineering</td>
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</table>
Adfluvial fish – Fish that inhabit freshwater lakes or reservoirs and migrate upstream to spawn in freshwater streams. An example is the bull trout in Keechelus Lake.

Aggradation (streambed) – Built up by the deposition of sediment.

Alluvial fan – A gradually widening mass of sand, silt, or clay deposited where a stream slows down, as at the mouth.

Anadromous fish – Fish that go from salt water to fresh water (usually up rivers) to spawn.

Autecology – The ecology of individual organisms or species.

Bedload (in a stream) – The part of the total stream sediment load that moves by sliding, rolling, or bouncing on or immediately above the stream bed, such that the larger heavier particles (boulders, pebbles, gravel) are transported by tractive or gravitational forces, or both, but at velocities less than the surrounding flow.

Best management practices (BMPs) – Methods that have been determined to be the most effective, practical means of preventing or reducing pollution from non-point sources.

Bottomless culvert – An arcing or 3-sided box type culvert with a natural floor.

Closed-canopy – Forest whose uppermost leafy layer (canopy) is dense, allowing little light penetration to the forest floor.

Colluvial deposits – Rock fragments, sand, etc., that accumulate on steep slopes or at the foot of cliffs.

Colubrid snakes – Any of a large family of generally nonpoisonous snakes, including garter snakes, racers, kingsnakes, etc.


Ecological connectivity (habitat and wildlife) – The movement of organisms and the occurrence of ecological processes across an ecosystem over time. Ecological connectivity across a landscape is important for animals because they need to access food resources, migrate to avoid severe weather, find mates, avoid natural events like wildfires, and disperse to maintain genetic fitness. Young animals also need to access unoccupied territories. In addition, ecological connectivity refers to the physical processes important in the environment, such as the movement of water from wetlands on one side of the highway to the other, or the passage of gravel and large floating trees down a stream channel. The
ultimate outcome of connectivity is natural sustaining populations across an ecosystem over time.

**Ecological integrity** – A condition that is characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change, and supporting processes.

**Ecotone** – A transitional zone between two adjacent ecological communities, containing species characteristic of both as well as other species occurring only within the zone.

**Edaphic** – Pertaining to the physical and chemical characteristics of a soil without reference to climate.

**Embedded** – Refers to a streambed characteristic in which the spaces between the bedload are filled with fine sediments reducing the space available for fish, amphibians, and macroinvertebrates for use as cover, resting, spawning, and feeding habitat.

**Escape ramp** – A ramp constructed inside a fenced highway right-of-way that allows animals inside the fenced area to escape safely.

**Fifth-field watersheds** – Watersheds that are 20,000 acres and larger.

**Fish passage** – The migration of fish from a lake or reservoir into tributary streams to that reservoir.

**High-permeability zone** – In landscape modeling of habitat characteristics, an area that has the physical and biological characteristics that are conducive to movement of individuals across the landscape.

**Hydric soils** – Soils that are formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

**Hydrologic connectivity zones** – Locations in the project area where moving water under the roadway is important. The hydrologic connectivity zones are typically located adjacent to wetlands, seeps, springs, or other visible signs of water. These areas are not necessarily located at stream crossings.

**Hydroperiods** (wetland) – The pattern of water level fluctuations in a wetland. Includes the depth, frequency, duration, and timing of inundation or flooding. Patterns can be daily, monthly, seasonal, annual or longer term.

**Hyporheic flow** – The flow of water through permeable soils under and beside the stream channel between the water table and surface water flow.

**Landscape permeability** – The ability of organisms to move freely across the landscape for the purposes of accessing food resources, migrating to avoid severe weather, and dispersing of young animals to unoccupied territories.
Large woody debris – Logs, stumps, rootwads, etc.

Legacy structure – A manmade structure made of natural materials such as logs, root wads, and rocks.

Macroinvertebrates – Stream-dwelling organisms without vertebrae that can be seen with the naked eye. Most macroinvertebrates are aquatic insects or the aquatic stages of insects. Examples include most aquatic insects, snails and crayfish.

Metic – Moderately moist.

Metapopulations – A group of partially isolated populations belonging to the same species; exchange of individuals occurs between such populations and individuals are able to recolonize sites from which the species have recently been extirpated.

Old growth – Referring to ecosystem or community, particularly a forest, which has not experienced intense or widespread disturbance for a long time relative to the life spans of the dominant species and which has entered a late successional stage; usually associated with high diversity of species, specialization and structural complexity (Johnson and O’Neal 2001).

Organic litter – The surface layer of the forest floor, composed of decaying organic material.

Palustrine – Pertaining to wet or marshy habitats that are not associated with lakes, rivers, or streams.

Properly functioning – State of the physical, chemical, and biological aspects of watershed ecosystems that will sustain healthy wildlife and salmonid populations. Properly functioning condition generally defines a range of values for several measurable criteria rather than specific, absolute values.

Recruitment (of LWD) – The introduction of woody material into a stream channel, floodplain, wetland or riparian area.

Riffle – A stretch of rough, rippled, or choppy water in a stream, produced by a shoal, reef, or shallow area.

Riparian – Adjacent to or living on the bank of a stream, river, or other body of water.

Riverine wetlands – Areas directly flooded by streamflow, including backwater or overbank flow, at least once every 5 years on average.

Road density – miles of road per square mile

Sedimentation – The depositing or formation of sediment.

Stream morphology – The geometric form and structure of a stream, controlled by geologic materials and processes, precipitation regime and stream hydrograph.
Stream simulation culverts – A culvert installation method recommended by the Washington State Department of Fish and Wildlife (WDFW) that creates similar fish passage conditions compared to the adjoining natural channel reaches. The stream simulation design criteria are: Culvert bed width = 1.2(stream channel width) +2 feet, and the slope of the culvert is < 1.25(Channel slope).

“Survey and Manage” species – Species identified in the Northwest Forest Plan (USDA and USDI 1994) as species of concern. These species can require field surveys prior to ground disturbing activities and/or may receive special management consideration.

Talus – Broken rock forming a more or less continuous layer that may or may not be covered by duff or leaf litter. Represents a unique habitat, with many species strongly associated with this habitat, such as Larch Mountain salamander and pika.

Understory – The smaller trees, saplings, and sometimes shrubs that grow beneath the large trees in a forest.

Ungulate – A mammal with hoofs.

Vagility – an organism’s ability to move about or disperse in a given environment.

Velocity barrier – An aquatic term referring to excessive water velocity over or through natural stream channel features or manmade structures that prevent juvenile or adult fish or other aquatic organisms from moving upstream.
CHAPTER 9

Acronyms and Abbreviations
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>BLM</td>
<td>U.S. Bureau of Land Management</td>
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<td>BMPs</td>
<td>Best management practices</td>
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<td>CEA</td>
<td>Connectivity Emphasis Area</td>
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<td>Ecology</td>
<td>Washington State Department of Ecology</td>
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<td>EIS</td>
<td>Environmental Impact Statement</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<tr>
<td>HCZ</td>
<td>Hydrologic connectivity zone</td>
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<td>IDT</td>
<td>Interdisciplinary Team</td>
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<tr>
<td>LSR</td>
<td>Late successional reserve (habitat)</td>
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<tr>
<td>LWD</td>
<td>large woody debris</td>
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<td>m</td>
<td>meters</td>
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<td>MDT</td>
<td>Mitigation Development Team</td>
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<td>MP</td>
<td>Mile post</td>
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<td>NWPPC</td>
<td>Northwest Power Planning Council</td>
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<td>pers. comm.</td>
<td>Personal communication</td>
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<td>USBR</td>
<td>U.S. Bureau of Reclamation</td>
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<td>USDA</td>
<td>U.S. Department of Agriculture</td>
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<td>USDI</td>
<td>U.S. Department of the Interior</td>
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<td>USFS</td>
<td>U.S. Forest Service</td>
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<td>USFWS</td>
<td>U.S. Fish and Wildlife Service</td>
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<td>WDFW</td>
<td>Washington State Department of Fish and Wildlife</td>
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<td>WSDOT</td>
<td>Washington State Department of Transportation</td>
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Definitions, Rating Systems, and Data Sources
# Definitions, Rating Systems, and Data Sources Used by Mitigation Development Team for Aquatic Elements

## Attachment Exhibit 1a

<table>
<thead>
<tr>
<th>Definition</th>
<th>Rating System</th>
<th>Performance Standards (see Performance Standards and BMPs for specific measures)</th>
<th>Information Sources</th>
</tr>
</thead>
</table>
| **Aquatic Habitat:** The ability of the water body to provide habitat for aquatic species -- aquatic species includes primarily fish and amphibians | Water bodies were rated as:  
- Properly functioning (PF);  
- At risk (AR); or  
- Not properly functioning (NPF) based on the condition of: substrate/ sediment; woody debris; water quality; riparian vegetation; and flow regime.  
Ratings were relative to the site’s potential to provide habitat under natural conditions. |  
- Stream Crossings  
- Hydrologic Connectivity  
- Maintenance Operations  
- Water Quality |  
- I-90 Snoqualmie Pass East Aquatic Species Discipline Report  
- Supplemented by field reconnaissance surveys by Bill Ehinger, USFS  
- Professional judgment of MDT |
| **Aquatic Linkages:** The ability for fish and other aquatic species to access aquatic habitat | Aquatic linkages were rated as:  
- Properly functioning (PF);  
- At risk (AR); or  
- Not properly functioning (NPF).  
Full and partial barriers were identified below, at, and above I-90, and included: road crossing barriers; natural barriers; and areas where the channel is seasonally dewatered. |  
- Stream Crossings |  
- I-90 Snoqualmie Pass East Aquatic Species Discipline Report |
| **Channel Function:** The degree to which the channel is able to function naturally, in dynamic equilibrium with watershed conditions | Stream channels were rated as:  
- Properly functioning (PF);  
- At risk (AR); or  
- Not properly functioning (NPF) based on: floodplain connectivity; groundwater/ surface water interactions; floodplain encroachment; channel confinement; and channel aggradation.  
Channels were rated relative to natural conditions for the stream.  
Channel relocations/ modifications resulting from original highway construction; impacts of highway maintenance activities; and the adequacy of stream crossing structures for accommodating flood flows, organic material, |  
- Stream Crossings  
- Water Quality |  
- I-90 Snoqualmie Pass East Aquatic Species Discipline Report  
- Supplemented by field reconnaissance surveys by Bill Ehinger, USFS  
- Professional judgment of MDT |
<table>
<thead>
<tr>
<th>Definition</th>
<th>Rating System</th>
<th>Performance Standards</th>
<th>Information Sources</th>
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<tbody>
<tr>
<td>Floodplains: The ability of floodplains to provide hydrologic, geomorphic, and habitat functions</td>
<td>Each stream was characterized as: • Naturally confined; • Artificially confined; or • Unconfined Artificial confinement and floodplain encroachments at highway crossings were then identified.</td>
<td>• Stream Crossings • Hydrologic Connectivity</td>
<td>• I-90 Snoqualmie Pass East Hydrologic Systems, Water Quality and Floodplains Discipline Reports • Supplemented by field reconnaissance surveys by Bill Ehinger, USFS • Professional judgment of MDT</td>
</tr>
<tr>
<td>Water Quality: The degree to which the water body was able to meet water quality standards for aquatic species and human beneficial uses</td>
<td>Streams that met all water quality standards were identified as: • Properly functioning (PF) Streams that failed to meet standards for one or more parameters were identified as: • Not properly functioning (NPF) and the parameters that failed to meet standards were listed. Streams that were 303(d) listed were noted, since these carry special regulatory requirements. Streams that could potentially fail standards if not restored were rated as • At risk (AR).</td>
<td>• Stream Crossings • Hydrologic Connectivity • Vegetation Management</td>
<td>• I-90 Snoqualmie Pass East Water Quality and Aquatic Species Discipline Reports • Supplemented by field observations by Bill Ehinger, USFS</td>
</tr>
<tr>
<td>Groundwater: The ability of the site to perform groundwater flow and recharge functions</td>
<td>The presence of important groundwater features was identified, including: outwash soils that provide groundwater recharge; till/outwash soils that indicate groundwater/surface water interactions; and groundwater flow that supports wetland and riparian habitat. Impairments to groundwater flow were identified, including: obstruction by the road prism; and compaction of soils by human activities.</td>
<td>• Hydrologic Connectivity</td>
<td>• I-90 Snoqualmie Pass East Hydrologic Systems and Wetlands Discipline Reports • Groundwater emergence zones mapped by Bill Ehinger, USFS • USDA soil survey maps • Professional judgment of MDT</td>
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</table>
Definitions, Rating Systems, and Data Sources Used by Mitigation Development Team for Aquatic Elements

Attachment Exhibit 1a

<table>
<thead>
<tr>
<th>Definition</th>
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<tr>
<td>Existing highway cut and fill construction methods were evaluated in the context of their location and their effect on: intercepting ground and surface water; lowering localized water tables; and altering and diverting natural flow paths along highway fill.</td>
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Performance Standards
(see Performance Standards and BMPs for specific measures)

Information Sources

Note: “NPF”, “At risk”, “PF” – designations do not reflect regulatory definitions.

1 The Definition, Rating System, Performance Standards and Information Sources for Wetlands, Geomorphic Functions, and Human Features have been combined with, and can be found in, the Definitions, Rating Systems and Data Sources sheet for Terrestrial Elements.

2 Keechelus Lake was not independently evaluated by the MDT at the September retreat. Evaluation of this water body has been deferred to the Section 7 consultation process.
Definitions, Rating Systems, and Data Sources Used by Mitigation Development Team for Terrestrial Elements
Attachment Exhibit 1b

<table>
<thead>
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<th>Definition</th>
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<th>Performance Standards</th>
<th>Information Sources</th>
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<tr>
<td>Soils: Certain soil types that are associated with rare low mobility species</td>
<td>The presence of rare/special soil types indicated as: Yes; and the soil type</td>
<td>• Terrestrial Species Movement</td>
<td>I-90 Snoqualmie Pass East Draft Species Distribution Assessment</td>
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<tr>
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<td>The absence of rare/special soil types indicated as: No</td>
<td>• Hydrologic Connectivity</td>
<td>Survey and Manage Progress Report</td>
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<td></td>
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<td>• Vegetation Management</td>
<td>I-90 Snoqualmie Pass East Draft Terrestrial Species Discipline Report</td>
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<tr>
<td>Terrestrial Habitat: All habitat adjacent to the highway corridor, including riparian, but excluding aquatic</td>
<td>Terrestrial habitat was rated as:</td>
<td>• Terrestrial Species Movement</td>
<td>I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment (Singleton and Lehmkuhl 2000)</td>
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<tr>
<td></td>
<td>• Properly functioning (PF);  At risk (AR); or • Not properly functioning (NPF)</td>
<td>• Vegetation Management</td>
<td>I-90 Snoqualmie Pass East Draft Species Distribution Assessment</td>
</tr>
<tr>
<td></td>
<td>The quality of habitat within 1-2 miles of I-90 was rated relative to undisturbed or natural conditions, with emphasis on habitats with high species diversity and rare habitat types. Land ownership and future management options were also considered.</td>
<td>• Policy Issues/Adjacent Land Issues</td>
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<td></td>
<td>Road segments on I-90 were ranked for landscape permeability (per Singleton, 2000).</td>
<td></td>
<td>I-90 Snoqualmie Pass East Draft Terrestrial Species Discipline Report</td>
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<tr>
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<td>Proximity of existing and potential habitat was considered as a function of habitat quality.</td>
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<td>Terrestrial Linkages: Habitat areas that provide for north/south and east/west movement of species, and are relatively undisturbed</td>
<td>The ability of existing habitat to support movement across the highway corridor for high, medium and low mobility species was rated relative to the site’s natural potential as: Properly functioning (PF); At risk (AR)</td>
<td>• Terrestrial Species Movement</td>
<td>I-90 Snoqualmie Pass East draft Terrestrial Species Discipline Report</td>
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<tr>
<td></td>
<td>Terrestrial linkage areas with a high degree of disturbance from recreation, logging, or road densities in the area were identified as: Not properly functioning (NPF).</td>
<td>• Hydrologic Connectivity</td>
<td>Survey and Manage Progress Report</td>
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<td></td>
<td>Road segments on I-90 were ranked for landscape permeability (per Singleton, 2000).</td>
<td>• Vegetation Management</td>
<td>I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment (Singleton and Lehmkuhl 2000)</td>
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<td></td>
<td></td>
<td></td>
<td>I-90 Snoqualmie Pass East Draft Species Distribution Assessment</td>
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### Definitions, Rating Systems, and Data Sources Used by Mitigation Development Team for Terrestrial Elements\(^1\)

**Attachment Exhibit 1b**

<table>
<thead>
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<th>Rating System</th>
<th>Performance Standards (see Performance Standards and BMPs for specific measures)</th>
<th>Information Sources</th>
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</thead>
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<tr>
<td><strong>Wetlands:</strong></td>
<td>Wetlands were identified as:</td>
<td>• Terrestrial Species Movement</td>
<td>• I-90 Snoqualmie Pass East Wetlands Discipline Report</td>
</tr>
<tr>
<td>• The presence and quality of wetland habitat at or near the I-90 right-of-way</td>
<td>• Present if wetlands were known to exist within the highway corridor, or in adjacent areas of drainages that cross the highway.</td>
<td>• Stream Crossings</td>
<td>• NWI maps</td>
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<tr>
<td>• Areas meeting regulatory criteria as wetlands (possessing the three criteria of hydrology, soils, and plants)</td>
<td>The quality was rated as: <strong>High, Medium</strong>, or <strong>Low</strong> based on: their ability to provide wetland functions; maturity and/or uniqueness of vegetation; size; and association with key habitat.</td>
<td>• Hydrologic Connectivity</td>
<td>• USDA soil survey maps</td>
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<tr>
<td></td>
<td>Impairments to wetlands due to: fill; loss of connectivity; or hydrologic alternations were identified.</td>
<td>• Maintenance Operations</td>
<td>• Wetland areas mapped by Bill Ehinger, USFS, along the I-90 right-of-way</td>
</tr>
<tr>
<td></td>
<td>Existing highway cut and fill construction methods were evaluated in the context of their location and their effect on: intercepting ground and surface water; lowering localized water tables; and altering and diverting natural flow paths.</td>
<td>• Water Quality</td>
<td>• Professional judgment of MDT</td>
</tr>
<tr>
<td><strong>Geomorphic Functions:</strong> Special geomorphic features and factors (such as unconfined streams, alluvial fans, etc.) that may constitute unique habitats and present opportunities to enhance ecological connectivity across the highway corridor</td>
<td>The presence of special geomorphic features was noted, including: debris flows; alluvial fans; landslide zones; and channel migration zones.</td>
<td>• Topographic maps</td>
<td>• I-90 Snoqualmie Pass East discipline reports</td>
</tr>
<tr>
<td></td>
<td>Human activities (high, medium, or low use within ½ mile of roadway crossing or segment) and features that influence aquatic systems were identified, including: reservoir operation; timber harvest; upstream road/roads (including USFS roads); powerline corridors; recreational activities;</td>
<td>• Stream Crossings</td>
<td>• Aerial photos</td>
</tr>
<tr>
<td></td>
<td>Human activities (high, medium, or low use within ½ mile of roadway crossing or segment) and features that influence aquatic systems were identified, including: reservoir operation; timber harvest; upstream road/roads (including USFS roads); powerline corridors; recreational activities;</td>
<td>• Hydrologic Connectivity</td>
<td>• Local knowledge</td>
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<tr>
<td></td>
<td>Past or ongoing human activities that impede natural ecosystem functions or species</td>
<td>• Maintenance Operations</td>
<td>• Professional judgment of MDT</td>
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<td></td>
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<td>• Water Quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Policy Issues/Adjacent Land Issues</td>
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Definitions, Rating Systems, and Data Sources Used by Mitigation Development Team for Terrestrial Elements¹  
Attachment Exhibit 1b

<table>
<thead>
<tr>
<th>Definition</th>
<th>Rating System</th>
<th>Performance Standards (see Performance Standards and BMPs for specific measures)</th>
<th>Information Sources</th>
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<tbody>
<tr>
<td>presence by altering the physical environment or discouraging wildlife use</td>
<td>development; and channel modifications.</td>
<td></td>
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</tbody>
</table>

Note: “NPF”, “At risk”, “PF” – designations do not reflect regulatory definitions.

¹ The Definition, Rating System, Performance Standards and Information Sources for Wetlands, Geomorphic Functions, and Human Features were combined with the Definitions, Rating Systems, and Data Sources for Aquatic Elements.
Species in the Project Area
### List of Wildlife Species in the Project Area
#### Attachment Exhibit 2-1

<table>
<thead>
<tr>
<th>Species</th>
<th>Gold Creek</th>
<th>Price/ Noble Creeks Area</th>
<th>Bonnie Creek</th>
<th>Swamp Creek Area</th>
<th>Toll Creek</th>
<th>Cedar Creek</th>
<th>Telephone Creek</th>
<th>Hudson Creek</th>
<th>Easton Hill Area</th>
<th>Kachess River</th>
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<tbody>
<tr>
<td><strong>Mollusks</strong></td>
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<tr>
<td>Ancotrema sportella</td>
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<td>Ariolimax columbianus</td>
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<td>Arion ater</td>
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<td>Columella alticola</td>
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# List of Wildlife Species in the Project Area

**Attachment Exhibit 2-1**

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<th>Toll Creek</th>
<th>Cedar Creek</th>
<th>Telephone Creek</th>
<th>Hudson Creek</th>
<th>Easton Hill Area</th>
<th>Kachess River</th>
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<td>Townsend’s chipmunk (Tamias townsendii cooperi)</td>
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<tr>
<td>Hoary marmot (Marmota caligata cascadiensis)</td>
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<tr>
<td>Golden mantled ground squirrel (Spermophilus</td>
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### List of Wildlife Species in the Project Area
**Attachment Exhibit 2-1**

<table>
<thead>
<tr>
<th>Species</th>
<th>Gold Creek</th>
<th>Price/ Nobel Creeks Area</th>
<th>Bonnie Creek</th>
<th>Swamp Creek Area</th>
<th>Toll Creek</th>
<th>Cedar Creek</th>
<th>Telephone Creek</th>
<th>Hudson Creek</th>
<th>Easton Hill Area</th>
<th>Kachess River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beechey ground squirrel (Otospermophilus beecheyi)</td>
<td>X</td>
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<tr>
<td>Douglas squirrel (Tamiasciurus douglasi)</td>
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<tr>
<td>Northern flying squirrel (Glaucomys sabrinus fuliginosus)</td>
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<tr>
<td>Northern pocket gopher (Thomomys talpoides fuscus)</td>
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<tr>
<td>Beaver (Castor canadensis)</td>
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<tr>
<td>Deer mouse (Peromyscus maniculatus)</td>
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<tr>
<td>Forest deer mouse (Peromyscus oreas)</td>
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<tr>
<td>Bushy-tailed woodrat (Neotoma cinerea occidentalis)</td>
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<tr>
<td>Gapper’s red-backed mouse</td>
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<tr>
<td>Heather vole (Phenacomys intermedius oramontis)</td>
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<tr>
<td>Montane vole (Microtus montanus canascens)</td>
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<tr>
<td>Long-tailed vole (Microtus longicaudus)</td>
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<tr>
<td>Creeping vole (Microtus oregoni oregoni)</td>
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<tr>
<td>Water vole (Microtus richardsoni arvicoloides)</td>
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<td>Pacific jumping mouse (Zapus trinotatus trinotatus)</td>
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<tr>
<td>Porcupine (Erethizon dorsatum)</td>
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<tr>
<td>Mountain goat (Oreamnos americanus)</td>
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#### Mammals

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<tr>
<th>Species</th>
<th>Gold Creek</th>
<th>Price/ Nobel Creeks Area</th>
<th>Bonnie Creek</th>
<th>Swamp Creek Area</th>
<th>Toll Creek</th>
<th>Cedar Creek</th>
<th>Telephone Creek</th>
<th>Hudson Creek</th>
<th>Easton Hill Area</th>
<th>Kachess River</th>
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</thead>
<tbody>
<tr>
<td>Marten (Martes americana)</td>
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<tr>
<td>River otter (Lutra canadensis)</td>
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<tr>
<td>Long-tailed weasel (Mustela frenata)</td>
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<tr>
<td>Short-tailed weasel (Mustela erminea)</td>
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<td>Fisher (Martes pennanti)</td>
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<tr>
<td>Striped skunk (Mephitis mephitis)</td>
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<tr>
<td>Spotted skunk (Spilogale gracilis)</td>
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<td>Wolverine (Gulo gulo)</td>
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<tr>
<td>Raccoon (Procyon lotor)</td>
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<tr>
<td>Bobcat (Lynx rufus)</td>
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<td>Mountain lion (Puma concolor)</td>
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<tr>
<td>Canada Lynx (Lynx canadensis)</td>
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<tr>
<td>Species</td>
<td>Gold Creek</td>
<td>Price/</td>
<td>Noble Creeks Area</td>
<td>Bonnie Creek</td>
<td>Swamp Creek Area</td>
<td>Toll Creek</td>
<td>Cedar Creek</td>
<td>Telephone Creek</td>
<td>Hudson Creek</td>
<td>Easton Hill Area</td>
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<tr>
<td>Cascade red fox (<em>Vulpes fulva</em>)</td>
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<tr>
<td>Coyote (<em>Canis latrans</em>)</td>
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<tr>
<td>Gray wolf (<em>Canis lupus</em>)</td>
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<tr>
<td>Black bear (<em>Ursus americanus</em>)</td>
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<tr>
<td>Grizzly bear (<em>Ursus arctos</em>)</td>
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<tr>
<td>Mule deer (<em>Cervus hemionus</em>)</td>
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<tr>
<td>Elk (<em>Cervus elaphus</em>)</td>
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</table>

S = Suspected to occur based on published literature of species range or surveys in the general area.
X = Documented occurrence based on Museum specimens, published literature or documented presence based on surveys.
### Native and Non-native Fish Species in the Project Area

**Attachment Exhibit 2-2**

<table>
<thead>
<tr>
<th>Common Name (Scientific Name)</th>
<th>Coal Creek</th>
<th>Gold Creek</th>
<th>Rocky Run</th>
<th>Keechelus Lake</th>
<th>Wolfe Creek</th>
<th>Resort Creek</th>
<th>Townsend Creek</th>
<th>Price/Noble Creeks</th>
<th>Bonnie Creek</th>
<th>Swamp Creek</th>
<th>Toll Creek</th>
<th>Cedar Creek</th>
<th>Telephone Creek</th>
<th>Hudson Creek</th>
<th>Kachess River</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Salmonids</strong> (trout, salmon, char, and whitefish family)</td>
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<tr>
<td>Mountain whitefish (Prosopium williamsoni)</td>
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<tr>
<td>Bull trout (Salvelinus confluentus)</td>
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<tr>
<td>Cutthroat trout (Oncorhynchus clarki lewisi)</td>
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<tr>
<td>Rainbow trout (Oncorhynchus mykiss)</td>
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<tr>
<td>Steelhead (Oncorhynchus mykiss)</td>
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<tr>
<td>Kokanee (Oncorhynchus nerka)</td>
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<tr>
<td>Chinook salmon (Oncorhynchus tshawytscha)</td>
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<tr>
<td>Coho salmon (Oncorhynchus kisutch)</td>
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<td><strong>Cyprinids</strong> (minnow and carp family)</td>
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<td>Redside shiner (Richardsonius balteatus)</td>
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<td>Northern pikeminnow (Ptychocheilus oregonensis)</td>
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<tr>
<td>Peamouth (Mylocheilus caurinus)</td>
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<td>Chiselmouth (Mylocheilus alutaceus)</td>
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<tr>
<td>Speckled dace (Rhinichthys osculus)</td>
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<tr>
<td>Longnose dace (Rhinichthys cataractae)</td>
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## Native and Non-native Fish Species in the Project Area
### Attachment Exhibit 2-2

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<th>Common Name (Scientific Name)</th>
<th>Coal Creek</th>
<th>Gold Creek</th>
<th>Rocky Run</th>
<th>Kachess Lake</th>
<th>Wolfe Creek</th>
<th>Resort Creek</th>
<th>Townsend Creek</th>
<th>Price/Noble Creeks</th>
<th>Bonnie Creek</th>
<th>Swamp Creek</th>
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<th>Telephone Creek</th>
<th>Hudson Creek</th>
<th>Kachess River</th>
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<tbody>
<tr>
<td><strong>Catostomidae</strong> (sucker family)</td>
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<tr>
<td>Largescale sucker (Catostomus macrocheilus)</td>
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<tr>
<td>Bridgelip sucker (Catostomus columbianus)</td>
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<td><strong>Cottids</strong> (sculpin family)</td>
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<td><strong>Salmonids</strong> (trout, salmon, char, and whitefish family)</td>
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<td>Brook trout (Salvelinus fontinalis)</td>
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* = Suspected distribution
Objectives and Performance Standards for Ecological Connectivity Structures and Development of a Mitigation Strategy
Attachment 3A
Objectives and Performance Standards for Ecological Connectivity Structures

OBJECTIVE #1 Move toward proper function and connection of hydrologic processes and aquatic and terrestrial habitats.

Connectivity Performance Standard 1.1 – At a minimum, wetlands, riparian habitats, floodplains, streams, upland forests, and unique habitats, such as talus, should receive primary attention when assessing existing conditions and developing recommendations for improvements to ecological and hydrologic connectivity.

Connectivity Performance Standard 1.2 – Improve hydrologic function and connections of stream channels, riparian areas, floodplains, wetland flow paths and hydroperiods, and groundwater/surface water interactions. Use WDFW stream simulation specifications in the design of the appropriate span for crossing structures.

Connectivity Performance Standard 1.3 – Design wildlife crossing structures to accommodate aquatic, riparian, and terrestrial habitat components.

Connectivity Performance Standard 1.4 – Protect existing habitat, particularly old growth and late-successional habitat. Where habitat loss occurs, reserve all trees, large logs, and root wads to be used adjacent to and within crossing structures.

Connectivity Performance Standard 1.5 – Where feasible, reduce the highway “footprint” and loss of habitat by bundling lanes (keeping them together rather than separated by a central median).

Connectivity Performance Standard 1.6 – In areas with elevated sections of highway, utilize vertical walls rather than fill slopes to reduce the loss of habitat and the risks associated with noxious weed spread and treatment.

Connectivity Performance Standard 1.7 – Use vertical walls or other measures to minimize filling of wetland habitats.

Connectivity Performance Standard 1.8 – Provide hydrologic connectivity structures that maintain properly functioning conditions and restore natural surface and subsurface flow paths through the road prism at wetlands, seepage zones, and areas of unconfined surface flow. These structures should minimize artificial flow concentration and conversion of subsurface flow to surface flow.

Connectivity Performance Standard 1.9 – Provide continuous wetland habitat through the highway right-of-way where there is potential linkage to high value wetlands. Restore natural topography, soil conditions, and wetland flow paths adjacent to and beneath connectivity structures intended to connect wetland habitats.
OBJECTIVE #2 – Increase the likelihood of sustaining local and regional native populations by reducing direct mortality.

Connectivity Performance Standard 2.1 – At a minimum, place connectivity structures in all areas of high wildlife activity/car-animal collisions.

Connectivity Performance Standard 2.2 – In areas with elevated sections of highway, utilize vertical walls rather than fill slopes to reduce access to roadway by animals.

Connectivity Performance Standard 2.3 – Discourage wildlife presence within the right-of-way by using salvage materials (from the project) and topographic features as barriers, whenever possible, and by using fencing, walls, and other artificial barriers when needed.

Connectivity Performance Standard 2.4 – Install amphibian and reptile walls (short walls with lip) along wetland and upland habitat areas frequented by these species.

OBJECTIVE #3 – Reduce risks associated with demographic isolation and reduced genetic variability.

Connectivity Performance Standard 3.1 – Site crossings in areas with high landscape permeability; locate crossings that provide connectivity for both high- and low-mobility species within the three “linkage zones” associated with the mountain hemlock/subalpine fir, western hemlock/Pacific silver fir, and grand fir/Douglas-fir plant associations.

Connectivity Performance Standard 3.2 – Design connectivity structures to conform to topography.

Connectivity Performance Standard 3.3 – Locate wildlife crossing structures in areas where adjacent land ownership and land use is conducive to long-term ecological connectivity.

Connectivity Performance Standard 3.4 – Prioritize and allocate resources for wildlife connectivity structures based on consistency with long-term management goals of lands near the approach to wildlife crossing structures and the proper functioning of each structure.

Connectivity Performance Standard 3.5 – Provide a minimum of one large overpass or terrestrial underpass for each mile of constructed roadway.

Connectivity Performance Standard 3.6 – Provide additional crossing structures (e.g., full culvert, open-bottom culvert, concrete box culvert) at intervals of approximately 820 feet of highway, where constructible and feasible, to accommodate small and medium-sized animals with small home ranges.

Connectivity Performance Standard 3.7 – Where feasible, reduce the length of crossing structures by bundling lanes (keeping them together rather than separated by a central median).

Connectivity Performance Standard 3.8 – Maximize openness of structures (high, wide, and short from entrance to exit) by providing a minimum clearance of at least
16 feet (to provide 12 feet of clearance over the typical 4-foot snow depth). A clearance of up to 20 to 30 feet under structures may be desirable to allow native vegetation to become established. This will facilitate plant-to-plant contact and native conditions, which would increase the structure’s effectiveness for low-mobility species.

**Connectivity Performance Standard 3.9** – Provide effective wildlife passage year round by using designs that accommodate snow depths (including snow plow berms typical of the project area; maintain a minimum of at least 16 feet (to provide 12 feet of clearance over the typical 4-foot snow depth).

**Connectivity Performance Standard 3.10** – Restore connectivity between unique habitats (e.g., talus) and old growth forests bisected by the existing road prism.

**Connectivity Performance Standard 3.11** – Accommodate both high- and low-mobility species dispersal in high priority CEAs (Gold, Price/Noble, Bonnie, Swamp, Toll, Hudson, Easton, and Kachess).

**Connectivity Performance Standard 3.12** – Locate crossing structures to maximize connectivity of different habitats within each CEA. In bridges of 120 feet or less, utilize vertical walls within the structure to maximize habitats connected.

**Connectivity Performance Standard 3.13** – Maximize continuity of native soils adjacent to and within bridges and on wildlife overpass structures.

**Connectivity Performance Standard 3.14** – Design wildlife crossing structures to minimize the intensity of noise and light emanating from the highway.

**Connectivity Performance Standard 3.15** – At a minimum, provide stream crossings that meet WDFW stream simulation specifications to allow passage of fish and other aquatic organisms. Consider adding debris (large wood) and a terrestrial bench inside the culverts.

**Connectivity Performance Standard 3.16** – Design crossing structures to allow for future species redistribution and recolonization due to improved habitat conditions, recovery plans, or re-introductions (e.g., grizzly bear, wolf, lynx, fisher).

**OBJECTIVE #4** – Reduce the need for intensive management of ecological resources in the project area by restoring self-sustaining, dynamic ecological processes and removing artificial constraints to ecosystem function.

**Connectivity Performance Standard 4.1** – Design all stream crossings to allow the natural movement of water, sediment, large wood, and debris flows through the road prism.

**Connectivity Performance Standard 4.2** – Span the portion of the active channel migration corridor of unconfined streams needed to restore floodplain, channel, and riparian functions.

**Connectivity Performance Standard 4.3** – Provide multiple stream paths to accommodate channel migration on alluvial fans.
**Connectivity Performance Standard 4.5** – Use vertical abutments or other methods to maximize the area of floodplain, riparian habitat, wetland, and unconfined flow beneath bridges and crossing structures, especially at shorter spans where fill slopes could encroach on and limit ecological functions under the structure. Presidential Executive Order 11990 (May 24, 1977) mandates minimizing the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands. In addition, Governor Booth Gardner issued Executive Orders 89-10 and 90-04 to achieve no overall net loss in acreage and function of Washington's remaining wetlands base. Use WDFW stream simulation specifications in the design of the appropriate span for crossing structures.

**Connectivity Performance Standard 4.6** – Minimize fill on floodplains and flood-prone areas. Presidential Executive Order 11988 (May 24, 1977) mandates federally funded projects to minimize floodplain impacts.

**Connectivity Performance Standard 4.7** – Design alternatives with minimal clearing widths to reduce impacts on existing vegetation.
Attachment 3B
Objectives and Performance Standards for Development of a Mitigation Strategy

While the MDT recognizes that focused efforts are needed to develop a comprehensive mitigation strategy for the I-90 Snoqualmie Pass East project, limited time was available to work on this task. However, the MDT has developed an extensive list of mitigation performance standards, based on our objectives, to serve as the foundation for a comprehensive mitigation strategy. These performance standards are summarized below.

OBJECTIVE #1 Move toward proper function and connection of hydrologic processes and aquatic and terrestrial habitats.

Mitigation Performance Standard 1.1 – At a minimum, wetlands, riparian habitats, floodplains, streams, upland forests, and unique habitats, such as talus, should receive primary attention for avoidance, minimization, and restoration to improve ecological and hydrologic connectivity.

Mitigation Performance Standard 1.2 – Protect existing habitat, particularly old growth and late-successional habitat. Where habitat loss occurs, reserve all trees, large logs, and root wads to be used adjacent to and within crossing structures.

Mitigation Performance Standard 1.3 – Improve hydrologic connections to the extent that project area stream channels, riparian areas, floodplains, wetland flow paths and hydroperiods, and groundwater/surface water interactions have moved or are moving to a properly functioning condition.

Mitigation Performance Standard 1.4 – Revegetate habitat disturbed during construction activities using native vegetation to discourage the growth of noxious weeds and to restore natural conditions.

Mitigation Performance Standard 1.5 – Where feasible, reduce the highway “footprint” and loss of habitat by bundling lanes (keeping them together rather than separated by a central median).

Mitigation Performance Standard 1.6 – In areas with elevated sections of highway, utilize vertical walls rather than fill slopes to reduce the loss of habitats and the risks associated with noxious weed spread and treatment.

Mitigation Performance Standard 1.7 – Use vertical walls or other measures to minimize filling of wetland habitats.

Mitigation Performance Standard 1.8 - Where and when feasible, locate material sources (e.g., gravel mines) for the I-90 Snoqualmie Pass East project in areas outside the active geomorphic floodplains in the Yakima River Basin.

Mitigation Performance Standard 1.9 – Compensate for forest/habitat lost during construction by purchasing replacement forest/habitat of similar type, at the appropriate
mitigation ratio, adjacent to the highway corridor. If possible, compensation should occur adjacent to highway crossing structures to improve their effectiveness.

**Mitigation Performance Standard 1.10** – Compensate for wetlands impacts by using a combination of structural elements, restoring altered habitats adjacent to the highway, and possibly purchasing land to preserve existing wetlands.

**OBJECTIVE #2** – Increase the likelihood of sustaining local and regional native populations by reducing direct mortality.

**Mitigation Performance Standard 2.1** – Post-project, substantially reduce large mammal mortality below baseline average annual mortality data.

**Mitigation Performance Standard 2.2** – Install fencing, barrier walls, and escape ramps based on best available science.

**Mitigation Performance Standard 2.3** – Inspect all fencing, barrier walls, and escape ramps annually (after snow melt) and maintain them to function properly.

**Mitigation Performance Standard 2.4** – Use legacy structures (e.g., large logs, root wads), vegetation and other habitat features, and fencing to facilitate wildlife use of large crossing structures.

**Mitigation Performance Standard 2.5** – In areas with elevated sections of highway, utilize vertical walls rather than fill slopes to reduce access to the roadway by animals.

**Mitigation Performance Standard 2.6** – Encourage use of crossing structures by wildlife by using wildlife exclusion structures such as fencing, rock walls, or other barriers along the highway to direct wildlife into crossing structures. Use topography and natural features as much as possible.

**Mitigation Performance Standard 2.7** – Provide escape ramps (primarily) or one-way gates (only where ramps are not possible) for animals that accidentally enter the highway corridor.

**Mitigation Performance Standard 2.8** – Provide increased lighting at fence ends and direct the end of the fence away from the highway in a “J” pattern where appropriate.

**Mitigation Performance Standard 2.9** – Install amphibian and reptile walls (short walls with lip) along wetland and upland habitat areas frequented by these species.

**Mitigation Performance Standard 2.10** – Encourage use of wildlife crossing structures by baiting and cutting trails leading to crossing structures where appropriate.

**Mitigation Performance Standard 2.11** – Inspect and maintain wildlife fences and walls a minimum of twice a year. Collaboratively develop a maintenance log and inspection schedule with WSDOT maintenance personnel.
OBJECTIVE #3 – Reduce risks associated with demographic isolation and reduced genetic variability.

Mitigation Performance Standard 3.1 – Develop a cooperative, multi-agency habitat connectivity plan with cooperative agreements for long-term land use management, land acquisition, and road crossings for public and private lands surrounding the project area.

Mitigation Performance Standard 3.2 – Develop and implement a cooperative, multi-agency recreation management plan to manage the areas adjacent to CEA crossing structures. This plan will address motorized and non-motorized recreation and the relocation of sno-park and campground facilities.

Mitigation Performance Standard 3.3 – Maximize openness of structures (high, wide, and short from entrance to exit) by providing a minimum clearance of 12 feet under average annual snow loads. A clearance of up to 20 to 30 feet under structures may be desirable to allow native vegetation to become established. This will facilitate plant-to-plant contact and native conditions, which would increase the structure’s effectiveness for low-mobility species.

Mitigation Performance Standard 3.4 – Restore connectivity between unique habitats (e.g., talus) and old growth forests bisected by the existing road prism.

Mitigation Performance Standard 3.5 – Maximize continuity of native soils adjacent to and within bridges and on wildlife overpass structures.

Mitigation Performance Standard 3.6 – Use crossing structure designs that provide natural lighting when possible and artificial lighting where needed to encourage development of native vegetation within structures.

Mitigation Performance Standard 3.7 – Where feasible, reduce the length of crossing structures by bundling lanes (keeping them together rather than separated by a central median).

Mitigation Performance Standard 3.8 – Maximize microhabitat complexity within crossing structures using salvage materials (logs, root wads, rocks, etc.) to encourage use by arboreal species, species associated with downed logs, and species associated with rocky substrates.

Mitigation Performance Standard 3.9 – Design connectivity structures to conform to topography.

Mitigation Performance Standard 3.10 – Design wildlife crossing structures for both high- and low-mobility species dispersal.

Mitigation Performance Standard 3.11 – Use salvage materials to maximize microhabitat complexity within crossing structures.

Mitigation Performance Standard 3.12 – Accommodate low-mobility species in crossings designed primarily for water passage when applicable.

Mitigation Performance Standard 3.13 – Design wildlife crossing structures to minimize the intensity of noise and light emanating from the highway.
Mitigation Performance Standard 3.14 – Ensure that crossing structure and CEA goals and objectives are consistent with Forest Plan management goals and objectives for timber harvest, roads, and management of recreation.

Mitigation Performance Standard 3.15 – Provide additional crossing structures (full culvert, open-bottom culvert, concrete box culvert, etc.) approximately 820 feet of highway as constructability allows to accommodate small and medium-sized animals with small home ranges.

Mitigation Performance Standard 3.16 – Maximize habitat cover in the vicinity of crossing structures’ entrances.

Mitigation Performance Standard 3.17 – Encourage development of native vegetation within the crossing structures by using designs that provide natural lighting whenever possible, and artificial lighting when needed.

OBJECTIVE #4 – Reduce the need for intensive management of ecological resources in the project area by restoring self-sustaining, dynamic ecological processes and removing artificial constraints to ecosystem function.

Mitigation Performance Standard 4.1 – Design all stream crossings to allow the natural movement of water, sediment, large wood, and debris flows through the road prism. Presidential Executive Order 11990 (May 24, 1977) mandates minimizing the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands. In addition, Governor Booth Gardner issued Executive Orders 89-10 and 90-04 to achieve no overall net loss in acreage and function of Washington's remaining wetlands base. Use WDFW stream simulation specifications in the design of the appropriate span for crossing structures.

Mitigation Performance Standard 4.2 – Provide multiple stream paths to accommodate channel migration on alluvial fans.

Mitigation Performance Standard 4.3 – Provide hydrologic connectivity structures that maintain properly functioning conditions and restore natural surface and subsurface flow paths through the road prism at low-gradient wetlands or areas of unconfined surface flow.

Mitigation Performance Standard 4.4 – Design wildlife crossing structures to accommodate aquatic, riparian, and terrestrial habitat components.

Mitigation Performance Standard 4.5 – Design all bridge supports within the floodplain area to accommodate channel changes throughout the span.

Mitigation Performance Standard 4.6 – Avoid soil compaction in floodplains, areas with hydric soils, seepage zones, and groundwater recharge areas. Minimize soil compaction in construction areas outside of the road prism. When these areas are disturbed during construction, restore soil physical conditions (including infiltration rates, bulk density, organic ground cover, and vegetation) to pre-construction conditions.
Mitigation Performance Standard 4.7 – Treat all stormwater runoff from the highway prior to discharge to streams and other water resources using low impact development techniques, best management practices, and guidelines identified in the WSDOT Highway Runoff Manual and the WSDOT Hydraulics Manual. Highway runoff should not be routed into drainage structures designed for hydrologic connectivity unless it has first been treated using natural or engineered dispersion.

Mitigation Performance Standard 4.8 – Establish special protocols for the application of herbicides, winter traction sand, and de-icer near streams and HCZs.

Mitigation Performance Standard 4.9 – Establish a spill response plan for HCZs and wildlife crossings.

Mitigation Performance Standard 4.10 – Use vertical abutments and other methods to maximize the area of floodplain, riparian habitat, wetland, and unconfined flow beneath bridges and crossing structures, especially at shorter spans where fill slopes could encroach on and limit ecological functions under the structure.

Mitigation Performance Standard 4.11 – Recycle or remove all fill from abandoned segments of roadway.

Mitigation Performance Standard 4.12 – Minimize direct impacts to mature habitat, especially for old-growth and late-successional stands and wetlands.

Mitigation Performance Standard 4.13 – Design alternatives with minimal clearing widths to reduce impacts to existing vegetation.


Mitigation Performance Standard 4.15 – Emphasize planting native, non-palatable, non-attractive vegetation within the right-of-way.

Mitigation Performance Standard 4.16 – Minimize exposed soils and over-steepened slopes during construction.

Mitigation Performance Standard 4.17 – Implement an invasive weed control program with realistic targets/performance standards that comply with land use plans/policies for all revegetation locations. Monitor existing weed conditions to document baseline conditions and to identify new invasives in the future.

Mitigation Performance Standard 4.18 – Coordinate compensatory mitigation efforts with land managers to ensure consistency with any vegetation plans.

Mitigation Performance Standard 4.19 – Where the natural (existing) condition is not desirable, attempt to achieve a desired condition.

Mitigation Performance Standard 4.20 – Identify living and non-living vegetation suitable for salvage prior to clearing/grubbing activities.

Mitigation Performance Standard 4.21 – Retain and use salvaged vegetation for restoration and revegetation efforts.
Mitigation Performance Standard 4.22 – Encourage the use of salvaged vegetation for restoration actions instead of new/imported plant material.

Mitigation Performance Standard 4.23 – In restoration/mitigation locations, attempt to mirror a reference location(s) that occurs on either or both sides of the highway.

Mitigation Performance Standard 4.24 – Design alternatives to reduce or eliminate the need for routine ditch and channel maintenance.


Mitigation Performance Standard 4.26 – Ensure ongoing monitoring of all compensatory mitigation sites for compliance with performance standards agreed upon as part of the mitigation plan.

Mitigation Performance Standard 4.27 – Devise a spill response plan for sensitive areas.

Mitigation Performance Standard 4.28 – Minimize/eliminate noxious weeds.

Mitigation Performance Standard 4.29 – Manage/control the application of traction sands around terrestrial undercrossings and aquatic passages to maintain native vegetation and water quality. Limit herbicide spraying within ¼ mile of crossing structures so as not to disturb native vegetation. EXCEPTION: Selective applications of herbicides may be required to control noxious weeds until native vegetation can re-establish.

OBJECTIVE #5 – Evaluate effectiveness of crossing structures to improve ecological and hydrologic connectivity and use adaptive management techniques to make needed improvements.

Mitigation Performance Standard 5.1 – Establish and implement monitoring plans at each CEA to determine if established performance standards for the project area are being met. When one or more performance standards for an individual CEA drop below average performance standards established for the project area, adaptive management procedures are triggered that determine cause and develop and implement corrective actions.

Mitigation Performance Standard 5.2 – Develop and implement a monitoring plan to address wildlife exclusion methods. This plan will include systematic data collection of observations of animals that have either climbed over or gotten though the fence, fence ends, other potential openings, gaps or deficiencies.

Mitigation Performance Standard 5.3 – Develop and implement a monitoring plan to evaluate the effectiveness of wildlife crossing structures.

Mitigation Performance Standard 5.4 – Develop and implement a monitoring plan to ensure that water quality is maintained and improved.
Mitigation Performance Standard 5.5 - Conduct ongoing monitoring of hydrologic and other physical attributes of aquatic, riparian, and wetland habitat within CEAs and near HCZs.
Hydrologic Connectivity –
A Forest Service Perspective
Environmental planning during project design is often guided by specific land management objectives, agency directives, statutory code, and permitting requirements; which vary by land ownership. On U.S. Forest Service-managed lands, the justification for maintaining and restoring hydrologic features, for hydrologic connectivity and support to riparian and aquatic species, is rooted in sound ecological science. However, understanding the process for implementing this requires a familiarity with the framework for National Forest management—a process that originates with statutory law, leads to the development of land management objectives, and ends with the application of effective site-specific standards and guidelines during construction and operation to achieve the desired ecological management objectives. This summary is intended to lay out this path to enhance the reader’s understanding of the land management objectives and standards and guidelines that apply to the I-90 corridor and are a part of National Forest Land and Resource Management Plans (LRMPs), which in turn guide decisions affecting such projects as right-of-way easements and special use permitting on National Forest lands.

**Statutory Framework**

The U.S. Forest Service is subject to the National Forest Management Act, 16 U.S.C. §§ 1600 et seq. (1994) (NFMA), and the regulations thereunder (see 36 C.F.R. part 219 [2005]). It is within this act, Section 1604(a), that the Secretary of Agriculture directs the U.S. Forest Service to "develop, maintain, and, as appropriate, revise land and resource management plans (LRMPs) for units of the National Forest System" 16 U.S.C. § 1604(a). All projects and decisions within each National Forest boundary shall be consistent with the LRMP. If a proposed site-specific decision is not consistent with the plan, the responsible official may modify the proposed decision to make it consistent with the plan, reject the proposal; or amend the plan to authorize the action (36 CFR 219.8).

At this time, consistency refers to implementing all applicable standards and guidelines contained within the Wenatchee National Forest LRMP; completed in 1990, as well as all subsequent amendments, including the 1997 Snoqualmie Pass Adaptive Management Area Plan, the 1994 Record of Decision (ROD) for the Northwest Forest Plan, and the March 2004 Record of Decision clarifying the Aquatic Conservation Strategy. It was the 1994 ROD that established a new land allocation, referred to as Riparian Reserves, as well as the Aquatic Conservation Strategy (ACS), with a purpose “to restore and maintain the ecological health of watersheds and aquatic ecosystems contained within them on public lands”
Riparian Reserves and Aquatic Conservation Strategy of the Northwest Forest Plan

Riparian Reserves were introduced as a principal component of the strategy, along with their associated standards and guidelines, and as a land allocation and principal tool for achieving the ACS objectives. Riparian Reserves are areas along all streams, wetlands, ponds, lakes, and unstable or potentially unstable areas where the conservation of aquatic and riparian-dependent terrestrial resources receives primary emphasis. These include groundwater seeps and springs. The widths of these reserves vary according to hydrologic feature type, size, and beneficial use. They range in width from 300 feet on either side of a perennial fish-bearing stream to a minimum of one site potential tree height or 100 feet (whichever is greatest) around the perimeter of a wetland boundary (wetlands <1 acre in size). “As a general rule, standards and guidelines for Riparian Reserves prohibit or regulate activities in Riparian Reserves that retard or prevent attainment of the Aquatic Conservation Strategy Objectives” (USDA 1994).

Examples of specific ACS objectives that pertain to hydrologic connectivity are listed below. These objectives were integrated into the performance standards for hydrologic connectivity contained in the I-90 Mitigation Development Team’s (MDT) report. ACS objectives are intended to be met at the fifth field watershed and larger landscape scales, over an extended period of time. In the context of this project, the Upper Yakima River Watershed is considered a fifth field Hydrologic Unit Code (HUC) by the U.S. Geological Survey.

- “Maintain and restore spatial and temporal connectivity within watersheds, including floodplains and wetlands. Provide chemically and physically unobstructed routes to areas critical for fulfilling life history requirements of aquatic and riparian dependent species.
- Maintain and restore water quality ... to support healthy riparian, aquatic, and wetland ecosystem.
- Maintain and restore instream flows sufficient to create and sustain riparian, aquatic and wetland habitats and to retain patterns of sediment, nutrient, and wood routing. The timing, magnitude, duration, and spatial distribution of peak, high, and low flows must be protected.
- Maintain and restore timing, variability, and duration of floodplain inundation and water table elevations in meadows and wetlands.”

The attainment of these objectives rests solidly upon the concept of site-specific implementation of Riparian Reserve standards and guidelines at the project scale.
A few examples of specific Riparian Reserve standards and guidelines that address these objectives include:

**Road Management (1994 ROD, C-32-33)**

RF-2. For each existing or planned road, meet Aquatic Conservation Strategy objectives by:

- minimizing road and landing locations in Riparian Reserves.
- minimizing disruption of natural hydrologic flow paths, including diversion of streamflow and interception of surface and subsurface flow.

RF-4. New culverts, bridges, and other stream crossings shall be constructed, and existing culverts, bridges and other stream crossings determined to pose a substantial risk to riparian conditions will be improved, to accommodate at least the 100-year flood, including associated bedload and debris… Crossings will be constructed and maintained to prevent diversion of streamflow out of the channel and down the road in the event of crossing failure.

**Lands (1994 ROD, C-37)**

LH-4. For activities other than surface water developments, issue leases, permits, rights-of-way, and easements to avoid adverse effects that retard or prevent attainment of Aquatic Conservation Strategy objectives. Adjust (such actions) … to eliminate adverse effects that retard or prevent the attainment of ACS objectives.

**Site-Specific Application**

Many of these standard and guidelines can be met with appropriately designed crossing structure spans and restoration mitigation at each of these hydrologic features and their Riparian Reserves. Performance standards that pertain to the preliminary project design and highway alignments can be found in the MDT report.

To appropriately consider all scales of hydrologic connectivity from the Forest Service perspective, these Riparian Reserves, ACS objectives, and standards and guidelines must be applied to hydrologic scales ranging from the smallest hydrologic features of seeps and springs upwards to the largest features of rivers and floodplains which drain fifth field HUC watersheds (20,000 acres and larger). While many state and federal agencies now recognize stream crossing designs for fish passage as necessary on fish-bearing waterbodies, the smaller hydrologic features are not uniformly recognized for their environmental value and protection. To address these features and their ecological role, the MDT has developed the concept of Hydrologic Connectivity Zones (HCZ). These zones have been delineated within Connectivity Emphasis Areas (CEAs) that exhibit hydrologic features such as small streams, wetlands, groundwater upwelling, and
seepage faces, and where traditional highway crossing designs will not achieve landscape scale ecological connectivity. They are intended to be a design tool to highlight areas where Riparian Reserves exist and where the ACS objectives, identified above, apply. While the MDT focused on CEAs specifically, hydrologic features that exist outside of CEAs along the project corridor will need similar performance standards applied.

The scale of the I-90 project represents a potential to affect the attainment of ACS objectives for hydrologic connectivity at the “fifth field watershed scale … over the long-term.” The scale of the impacts from this highway project extends across varying spatial and temporal scales. Potential impacts from construction and operation will likely extend over a period of decades on the temporal scale, while expanding across a spatial scale of nearly 15 miles of right-of-way, with potential downstream effects beyond the immediate project boundary. Throughout the Upper Yakima Watershed, there exists the potential to affect more than 12 streams and floodplains, 10 wetland complexes, and numerous seeps and springs. On National Forest lands, each of these areas requires the establishment of a Riparian Reserve width, with specific Riparian Reserve standards and guidelines.

At some later date in this project, the U.S. Forest Service will consider a decision of project consistency with the forest plan, which includes the ACS objectives. It will require the evaluation of the project design and mitigation in the context of these standards and guidelines and objectives. After assessing the short-term, long-term, and cumulative environmental impacts of the project, the Okanogan-Wenatchee National Forest Supervisor will consider the decision to transfer National Forest System lands for highway purposes. The Forest Supervisor must be able to conclude that the I-90 Snoqualmie Pass East Project has been designed to contribute to maintaining or restoring the fifth-field watershed over the long term through consistency with these Riparian Reserve standards and guidelines. This will ensure that over the long term, the project will “meet,” “not adversely affect,” “not retard or prevent attainment of,” or “otherwise achieve attainment of the ACS objectives” (ROD 1994, page 12).
ATTACHMENT 5

Openness Ratios
## Keechelus Lake Alignment Alternative Stream Crossing Structures at CEAs

### Attachment Exhibit 5-1

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MP</th>
<th>ATTRIBUTES</th>
<th>EXISTING STRUCTURE</th>
<th>TUNNEL ALIGNMENT ALTERNATIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky Run Creek</td>
<td>56.8</td>
<td>Double 6-foot Corrugated Metal Culvert</td>
<td><strong>Single-Span Bridge (Both Aligns)</strong></td>
<td>120 ft. approx. 120 ft. approx. 120 ft. approx. 120 ft. approx.</td>
</tr>
<tr>
<td>Structure Type</td>
<td></td>
<td>Width (W) 37 ft. approx. 12 ft.</td>
<td>Height (H) 11 ft. min. 6 ft.</td>
<td>Opening Area (W x H)*** 165 sq. ft. 72 sq. ft. 70 ft.</td>
</tr>
<tr>
<td>Height (H)</td>
<td></td>
<td>6 ft.</td>
<td>8 ft. min.</td>
<td>8 ft. min.</td>
</tr>
<tr>
<td>Opening Area (W x H)***</td>
<td></td>
<td>165 sq. ft. 72 sq. ft.</td>
<td>960 sq. ft. 960 sq. ft. 960 sq. ft.</td>
<td></td>
</tr>
<tr>
<td>Length (L)</td>
<td></td>
<td>40 ft. 75 ft.</td>
<td>70 ft.</td>
<td>70 ft.</td>
</tr>
<tr>
<td>Openness Ratio (W x H)/L</td>
<td></td>
<td>0.96</td>
<td>13.71</td>
<td>13.71</td>
</tr>
</tbody>
</table>

### Wolfe Creek 57.4

| Structure Type | 6-foot Corrugated Metal Culvert | Width (W) 6 ft. | Height (H) 6 ft. | Opening Area (W x H)*** 28 sq. ft. 200 sq. ft. |
| Height (H)     | 8 ft. min. | 8 ft. min. | 8 ft. min. | 200 sq. ft. |
| Opening Area (W x H)*** | 28 sq. ft. | 200 sq. ft. |
| Length (L)     | 150 ft. | 75 ft. | 75 ft. | 75 ft. |
| Openness Ratio (W x H)/L | 0.19 | 2.67 | 2.67 | 2.67 |

### Resort Creek 59.4

| Structure Type | 6-foot Corrugated Metal Culvert | Width (W) 6 ft. | Height (H) 6 ft. | Opening Area (W x H)*** 28 sq. ft. 1000 sq. ft. 1000 sq. ft. |
| Height (H)     | 10 ft. min. | 10 ft. min. | 10 ft. min. | 1000 sq. ft. |
| Opening Area (W x H)*** | 28 sq. ft. | 1000 sq. ft. |
| Length (L)     | 150 ft. | 62 ft. | 62 ft. | 62 ft. |
| Openness Ratio (W x H)/L | 0.19 | 16.13 | 16.13 | 10.67 |

### Keechelus Lake Alignment Alternative Stream Crossing Structures at CEAs

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MP</th>
<th>ATTRIBUTES</th>
<th>EXISTING STRUCTURE</th>
<th>TUNNEL ALIGNMENT ALTERNATIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky Run Creek</td>
<td>56.8</td>
<td>Double 6-foot Corrugated Metal Culvert</td>
<td><strong>Single-Span Bridge (Both Aligns)</strong></td>
<td>120 ft. approx. 120 ft. approx. 120 ft. approx. 120 ft. approx.</td>
</tr>
<tr>
<td>Structure Type</td>
<td></td>
<td>Width (W) 37 ft. approx. 12 ft.</td>
<td>Height (H) 11 ft. min. 6 ft.</td>
<td>Opening Area (W x H)*** 165 sq. ft. 72 sq. ft. 70 ft.</td>
</tr>
<tr>
<td>Height (H)</td>
<td></td>
<td>6 ft.</td>
<td>8 ft. min.</td>
<td>8 ft. min.</td>
</tr>
<tr>
<td>Opening Area (W x H)***</td>
<td></td>
<td>165 sq. ft. 72 sq. ft.</td>
<td>960 sq. ft. 960 sq. ft. 960 sq. ft.</td>
<td></td>
</tr>
<tr>
<td>Length (L)</td>
<td></td>
<td>40 ft. 75 ft.</td>
<td>70 ft.</td>
<td>70 ft.</td>
</tr>
<tr>
<td>Openness Ratio (W x H)/L</td>
<td></td>
<td>0.96</td>
<td>13.71</td>
<td>13.71</td>
</tr>
</tbody>
</table>

### Wolfe Creek 57.4

| Structure Type | 6-foot Corrugated Metal Culvert | Width (W) 6 ft. | Height (H) 6 ft. | Opening Area (W x H)*** 28 sq. ft. 200 sq. ft. |
| Height (H)     | 8 ft. min. | 8 ft. min. | 8 ft. min. | 200 sq. ft. |
| Opening Area (W x H)*** | 28 sq. ft. | 200 sq. ft. |
| Length (L)     | 150 ft. | 75 ft. | 75 ft. | 75 ft. |
| Openness Ratio (W x H)/L | 0.19 | 2.67 | 2.67 | 2.67 |

### Resort Creek 59.4

| Structure Type | 6-foot Corrugated Metal Culvert | Width (W) 6 ft. | Height (H) 6 ft. | Opening Area (W x H)*** 28 sq. ft. 1000 sq. ft. 1000 sq. ft. |
| Height (H)     | 10 ft. min. | 10 ft. min. | 10 ft. min. | 1000 sq. ft. |
| Opening Area (W x H)*** | 28 sq. ft. | 1000 sq. ft. |
| Length (L)     | 150 ft. | 62 ft. | 62 ft. | 62 ft. |
| Openness Ratio (W x H)/L | 0.19 | 16.13 | 16.13 | 10.67 |

*** All "Opening Areas" for proposed single-span bridges were calculated assuming vertical bridge abutments while all multi-spans were assumed to have 2:1 H/V abutment slopes (thus decreasing the Opening Area)

The dimensions shown are approximate, and were developed for preliminary evaluation and assessment of impacts. Actual bridge and culvert sizes will vary, depending on the topography and intended purpose of the structure.

If additional clearance is needed on single-span bridges, thin slab spans may be used to obtain clearance for bridge lengths of up to 80 feet.

Bottomless culverts will be included at locations where fish passage is required, and will be designed using standards required by WDF&W and WSDOT.

Culverts will be used in non-fish-bearing streams and will be designed to the appropriate hydraulic standards.

For adjacent structures only the smaller openness ratio is displayed.
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MP</th>
<th>ATTRIBUTES</th>
<th>EXISTING STRUCTURE</th>
<th>Improvement Package</th>
<th>DLOCATION</th>
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</thead>
<tbody>
<tr>
<td>Gold Creek West</td>
<td>55.3</td>
<td>No Structure</td>
<td>Twin Bridges¹</td>
<td>Twin Bridges¹</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structure Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width (W)</td>
<td>120 ft. approx.</td>
<td>120 ft. approx.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Height (H)¹</td>
<td>21 ft. avg.</td>
<td>21 ft. avg.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening Area (W x H)***</td>
<td>2520 sq. ft.</td>
<td>1440 sq. ft.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length (L)</td>
<td>62 ft.</td>
<td>62 ft.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Openness Ratio (W x H)/L</td>
<td>41</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Gold Creek</td>
<td>55.4</td>
<td>Multi-Span Bridge Multi-Span Bridge</td>
<td>Twin Bridges² Multi-Span Bridge</td>
<td>Twin Bridges² Multi-Span Bridge</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structure Type</td>
<td>EB</td>
<td>WB</td>
<td></td>
</tr>
<tr>
<td>Townsend Creek</td>
<td>60.6</td>
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<td>Large Span</td>
<td>Large Span</td>
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</tr>
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<td></td>
<td></td>
<td>Structure Type</td>
<td>6” diam. CM Culvert¹</td>
<td>Bottomless Culvert¹</td>
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<td>25 ft. approx.</td>
</tr>
<tr>
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<td>12 ft. approx.</td>
<td>12 ft. approx.</td>
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<tr>
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<td>300 sq. ft.</td>
<td>300 sq. ft.</td>
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<tr>
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<td>Openness Ratio (W x H)/L</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Price/Noble Vicinity West (Rock Knob)</td>
<td>60.8</td>
<td>No Structure</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structure Type</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width (W)</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Height (H)¹</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening Area (W x H)***</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length (L)</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Openness Ratio (W x H)/L</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td>Price/Noble Vicinity West</td>
<td>60.9</td>
<td>No Structure</td>
<td>No Structure</td>
<td>No Structure</td>
<td>Wildlife Overcrossing Structure (Both Aligns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structure Type</td>
<td>Twin Bridges²</td>
<td>Twin Bridges²</td>
<td>Twin Bridges²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width (W)</td>
<td>120 ft. approx.</td>
<td>120 ft. approx.</td>
<td>120 ft. approx.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Height (H)¹</td>
<td>21 ft. avg.</td>
<td>21 ft. avg.</td>
<td>21 ft. avg.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening Area (W x H)***</td>
<td>2280 sq. ft.</td>
<td>2280 sq. ft.</td>
<td>2280 sq. ft.</td>
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<tr>
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<td>60 ft.</td>
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<tr>
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<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Price Creek</td>
<td>61.3</td>
<td>Twin Multi-Span Bridges¹</td>
<td>Twin Multi-Span Bridges¹</td>
<td>Twin Bridges¹</td>
<td>Twin Bridges¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structure Type</td>
<td>Twin Multi-Span Bridges¹</td>
<td>Twin Multi-Span Bridges¹</td>
<td>Twin Bridges¹</td>
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<tr>
<td></td>
<td></td>
<td>Width (W)</td>
<td>10 ft.</td>
<td>800 ft. approx.</td>
<td>800 ft. approx.</td>
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<td></td>
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<td>Height (H)¹</td>
<td>15 ft. avg.</td>
<td>12 ft. avg.</td>
<td>11 ft. avg.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening Area (W x H)***</td>
<td>11550 sq. ft.</td>
<td>9312 sq. ft.</td>
<td>1320 sq. ft.</td>
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<tr>
<td></td>
<td></td>
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<td>60 ft.</td>
<td>60 ft.</td>
<td>60 ft.</td>
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<tr>
<td></td>
<td></td>
<td>Openness Ratio (W x H)/L</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Noble Creek</td>
<td>61.4</td>
<td>Twin Multi-Span Bridges for Price Creek Span Noble Creek Also</td>
<td>Twin Multi-Span Bridges for Price Creek Span Noble Creek Also</td>
<td>Twin Bridges¹</td>
<td>Twin Bridges¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structure Type</td>
<td>4&quot; diam. CM culvert¹</td>
<td>Twin Multi-Span Bridges for Price Creek Span Noble Creek Also</td>
<td>Twin Multi-Span Bridges for Price Creek Span Noble Creek Also</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Width (W)</td>
<td>4 ft.</td>
<td>120 ft. approx.</td>
<td>120 ft. approx.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Height (H)¹</td>
<td>4 ft.</td>
<td>10 ft. avg.</td>
<td>10 ft. avg.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opening Area (W x H)***</td>
<td>13 sq. ft.</td>
<td>1200 sq. ft.</td>
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<td>Length (L)</td>
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<td>60 ft.</td>
<td>60 ft.</td>
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<td>Openness Ratio (W x H)/L</td>
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<td>20</td>
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</table>
### Improvement Package Crossing Structure Attributes

**Attachment Exhibit 5-2**

<table>
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<tr>
<th>LOCATION</th>
<th>MP</th>
<th>ATTRIBUTES</th>
<th>EXISTING STRUCTURE</th>
<th>A</th>
<th>Improvement Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price/Noble Vicinity East</td>
<td>61.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure Type</td>
<td>2' diam. culverts</td>
<td>Twin Multi-Span Bridges¹</td>
<td>Hydrologic Connectivity Zone - Conveyance methods and limits to be determined through further study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width (W)</td>
<td>2 ft.</td>
<td>800 ft. approx.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (H)*</td>
<td>2 ft.</td>
<td>2 ft. avg.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opening Area (W x H)***</td>
<td>3 sq. ft.</td>
<td>1600 sq. ft.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Length (L)</td>
<td>250 ft.</td>
<td>60 ft.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Openness Ratio (W x H)/L</td>
<td>0</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonnie Creek West Fork</td>
<td>62.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure Type</td>
<td>2' diam. CM culvert</td>
<td>Twin Multi-Span Bridges¹</td>
<td>Hydrologic Connectivity Zone - Conveyance methods and limits to be determined through further study.</td>
<td></td>
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</tr>
<tr>
<td>Width (W)</td>
<td>6 ft.</td>
<td>600 ft. approx.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (H)*</td>
<td>6 ft.</td>
<td>23 ft. avg.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opening Area (W x H)***</td>
<td>3 sq. ft.</td>
<td>12742 sq. ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length (L)</td>
<td>150 ft.</td>
<td>60 ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Openness Ratio (W x H)/L</td>
<td>0</td>
<td>212</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonnie Creek East Fork</td>
<td>62.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure Type</td>
<td>6' X 6' box culvert</td>
<td>Twin Multi-Span Bridges Span Both West and East Forks</td>
<td>Hydrologic Connectivity Zone - Conveyance methods and limits to be determined through further study.</td>
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<td></td>
</tr>
<tr>
<td>Width (W)</td>
<td>6 ft.</td>
<td>240 ft. approx.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (H)*</td>
<td>6 ft.</td>
<td>21 ft. avg.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opening Area (W x H)***</td>
<td>36 sq. ft.</td>
<td>4116 sq. ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length (L)</td>
<td>150 ft.</td>
<td>60 ft.</td>
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<td></td>
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<tr>
<td>Openness Ratio (W x H)/L</td>
<td>0</td>
<td>69</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamp Creek Vicinity West</td>
<td>62.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Structure Type</td>
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<td>Twin Bridges¹</td>
<td>Hydrologic Connectivity Zone - Conveyance methods and limits to be determined through further study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width (W)</td>
<td>2 ft.</td>
<td>120 ft. approx.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (H)*</td>
<td>2 ft.</td>
<td>16 ft. avg.</td>
<td></td>
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<td></td>
</tr>
<tr>
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<td>2 sq. ft.</td>
<td>1920 sq. ft.</td>
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</tr>
<tr>
<td>Length (L)</td>
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</tr>
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<td>Openness Ratio (W x H)/L</td>
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<td>62.8</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure Type</td>
<td>8' double box culvert</td>
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<tr>
<td>Swamp Creek Vicinity East</td>
<td>63.3</td>
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<tr>
<td>Structure Type</td>
<td>18' diam. culvert</td>
<td>Twin Bridges¹</td>
<td>Hydrologic Connectivity Zone - Conveyance methods and limits to be determined through further study.</td>
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</tr>
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<td>Width (W)</td>
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<td>Height (H)*</td>
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<td>15 ft. avg.</td>
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<td>Opening Area (W x H)***</td>
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<td>Toll Creek Vicinity West</td>
<td>63.6</td>
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<td>Structure Type</td>
<td>8' X 8' box culvert</td>
<td>Twin Bridges¹</td>
<td>Bottomless Culvert¹</td>
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<td>Width (W)</td>
<td>8 ft.</td>
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<td>16 ft. approx.</td>
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<td>30</td>
<td>3</td>
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¹ The types of structures are indicated as follows:
- Twin Bridges: A twin bridge structure where both spans are connected by a common girder system.
- Twin Multi-Span Bridges: A structure with multiple spans, each connected by its own girder system.
- Bottomless Culvert: A culvert without a top closure, allowing free passage for water.

**Note:** The data provided includes dimensions and attributes of the existing structures, along with the proposed improvement packages for each location. The Hydrologic Connectivity Zone indicates areas where conveyance methods and limits need further study.
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MP</th>
<th>ATTRIBUTES</th>
<th>EXISTING STRUCTURE</th>
<th>Improvement Package</th>
<th>D</th>
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<td>6 ft. approx.</td>
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<td>5 ft. approx.</td>
<td>5 ft. approx.</td>
<td>5 ft. approx.</td>
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<td>0</td>
<td>0</td>
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<td>4 ft. approx.</td>
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<td>1 sq. ft.</td>
<td>1 sq. ft.</td>
<td>1 sq. ft.</td>
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<tr>
<td>Length (L)</td>
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<td>Twin Bridges2</td>
<td>Culvert3</td>
<td>Culvert</td>
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<tr>
<td>Width (W)</td>
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<td>Height (H)*</td>
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<td>Structure Type</td>
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<td>Bridge WB</td>
<td>Bridge EB</td>
<td>Bridge EB</td>
<td>Bridge EB</td>
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<td>150 ft. approx.</td>
<td>150 ft. approx.</td>
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<tr>
<td>Height (H)*</td>
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<td>100 ft. **</td>
<td>21 ft. avg.</td>
<td>100 ft. **</td>
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<td>Opening Area (W x H)**</td>
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<td>15000 sq. ft.</td>
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<tr>
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<td>Wildlife Overcrossing Structure WB</td>
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<td>Structure Type</td>
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<td>Bridge WB</td>
<td>Bridge EB</td>
<td>Bridge EB</td>
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<td>150 ft. approx.</td>
<td>100 ft. **</td>
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<td>100 ft. **</td>
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<td>60</td>
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## Improvement Package Crossing Structure Attributes
### Attachment Exhibit 5-2

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MP</th>
<th>ATTRIBUTES</th>
<th>EXISTING STRUCTURE</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tr>
<td>Lake Kachess Vicinity (County Road)</td>
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<td>Structure Type</td>
<td>Single Span Bridge EB</td>
<td>Twin Bridges</td>
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<td>Widen Existing Bridge (Both Aligns)</td>
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<td>17 ft. min.</td>
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<td>16 ft.</td>
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<td>Kachess River</td>
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<td>Multi-Span Bridge EB/WB</td>
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<td>Widen Existing Bridge (Both Aligns)</td>
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<td>25</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Openness Ratio**

| Lake Kachess Vicinity (County Road) | 69.5 | 55 | 986 | 740 | 250 | 356 |

1. Identical bridges or culverts will be used for both eastbound and westbound alignments.

* Proposed bridge height (clearance) is based upon an average of the lowest clearance available beneath the proposed roadway at fifty-foot intervals along the roadway length of the structure.

** Wildlife overcrossing structures were assigned a maximum height of 100 feet for comparative purposes.

*** All "Opening Areas" for proposed bridges were calculated assuming vertical bridge abutments within the structure.

The dimensions shown are approximate, and were developed for preliminary evaluation and assessment of impacts. Actual bridge and culvert sizes will vary, depending on the topography and intended purpose of the structure.

Bottomless culverts will be included at locations where fish passage is required, and will be designed using standards required by WDFW and WSDOT. Culverts will be used in non-fish bearing streams and will be designed to the appropriate hydraulic standards.

At Price/Noble, Bonnie, and Swamp Creek CEsAs, as well as other areas, minor culverts will be installed in all packages as needed to provide added hydrologic connectivity. For adjacent (twin) structures only the smaller openness ratio is displayed.