Ecology and Transportation: The I-90 Snoqualmie Pass East Project’s Design Engineering
Challenges of Integrating Transportation Needs with Landscape-Level Connectivity and
Transportation Corridor Crossing Objectives

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ECOLOGY AND TRANSPORTATION: THE I-90 SNOQUALMIE PASS EAST PROJECT'S DESIGN ENGINEERING CHALLENGES OF INTEGRATING TRANSPORTATION NEEDS WITH LANDSCAPE-LEVEL CONNECTIVITY AND TRANSPORTATION CORRIDOR CROSSING OBJECTIVES

The Washington State Department of Transportation’s I-90 Snoqualmie Pass East Project (I-90 Project) has presented WSDOT engineers with many unique design challenges when integrating the ecological needs of the area with the transportation objectives of the project.

In addition to addressing issues regarding capacity, deteriorating concrete pavement, unstable rock slopes, and road closures associated with avalanches, a significant project need is to improve ecological connectivity of the area. I-90 is a physical barrier to the north-south movement of fish and wildlife. Wildlife attempting to cross over the interstate present a safety concern to motorists, and the barrier I-90 forms between upstream and downstream aquatic habitats affects fish passage and hydrologic processes.

To identify areas where investments in ecological connectivity should be made, WSDOT worked with dozens of agencies that manage land resources in the project area to design bridges and culverts that improve wildlife and aquatic connections. Integrating ecological objectives presented many design engineering challenges due to the project area’s unfavorable construction conditions. Trade-offs and compromises between WSDOT and land resource managers were needed to find suitable solutions to problems. Issues that required compromises included: eliminating scour issues while maximizing restoration areas; improving ground conditions for foundations without impacts to wetlands, endangered species, and footprint; creating habitat connections while treating stormwater; and designing bridges for clearance and connecting habitat.
The Washington State Department of Transportation’s (WSDOT) I-90 Snoqualmie Pass East Project (I-90 Project) is a 15-mile highway improvement project that will ensure the continued availability of Interstate 90 as a primary statewide corridor. Through the I-90 Project, WSDOT will improve the safety and reliability of this corridor by reducing avalanche risks to the traveling public, minimizing road closures required for avalanche control work, and reducing the risk of rock and debris falling onto the interstate from unstable slopes. WSDOT will also fix structural deficiencies and provide for the recent and predicted increases in traffic volume. Ecological connectivity is another important project component. WSDOT will work to reduce wildlife / vehicle collisions by re-connecting habitat across I-90 and improving mobility of aquatic species and wildlife.

Plans for the project include widening the existing four lane interstate to six lanes, replacing deteriorated concrete pavement, straightening sharp roadway curves, stabilizing unstable rock slopes, building a new, more efficient snowshed (a concrete shed covering the roadway to provide permanent protection from avalanches and other falling debris to travelers passing through Snoqualmie Pass), and constructing wildlife crossings structures.

The first five miles of the I-90 Project from Hyak to Keechelus Dam received funding in 2005 from the Washington State Legislature through the Transportation Partnership Account – a 9.5 cent increase in the gas tax – in the amount of $595 million. The remaining 10 project miles from Keechelus Dam to Easton remain unfunded.

The I-90 Project corridor is located high along a mountain pass in the Central Cascades. The area’s extreme weather conditions and inherent geographical and geotechnical complexities has presented WSDOT I-90 Project engineers with many challenges when designing this improvement project. Integrating ecological connectivity objectives with transportation objectives has also presented challenges. Conflicts in objectives regarding crossing structure designs often surfaced that required the I-90 Project design team and partnering resource agencies to compromise and accept trade-offs in order to move the project forward. Finding the right designs to optimize benefits required a great deal of collaboration, technical investigation, and engineering review.

In the following paper, several case studies will be provided depicting how conflicts in design between WSDOT engineers and various resource agencies, inter-disciplinary teams, and technical committees were managed to resolve issues and reach compromises with satisfactory outcomes.

In order to understand how WSDOT and project stakeholders integrated transportation and ecological connectivity objectives into the I-90 Project, it’s first necessary to understand the environment in which WSDOT is working and the process for developing the project’s purpose and need.

I-90 PROJECT CORRIDOR ATTRIBUTES

- I-90 spans 300 miles in Washington state from the Port of Seattle to the Idaho state line, and then continues east across the United States to Boston, MA. I-90 is the major east-west transportation corridor across Washington and is vital to the state’s economy (see figure 1) (1).
Figure 1 shows Interstate 90, the I-90 Project location, and typical topography.

The I-90 Project improves a 15-mile portion of I-90, beginning on the eastern side of Snoqualmie Pass at milepost 55.1, just east of the Hyak Interchange, where the existing highway narrows from six lanes to four lanes. The project end point is at milepost 70.3 at the West Easton Interchange, where the terrain becomes flatter and the highway is straighter. This 15-mile stretch of I-90 is in Kittitas County, WA, and is predominately located on federal land within the Okanogan-Wenatchee National Forest.

The project corridor is located along a high mountain pass in the Central Cascades. The general topography is one of mountainous peaks and valleys. For the first six miles of the project area, I-90 runs along a narrow corridor between the shores of Keechelus Lake, a deep-water agricultural reservoir, and steep mountain slopes (see figure 2). These steep mountain slopes contain volcanic bedrock at varying depths that are subject to deep fissures and stress cracks with weakened slip planes, which when combined with high annual precipitation and freeze-thaw conditions, makes them susceptible to landslides, debris flow, and avalanches.

I-90 is built primarily within an easement on National Forest land. The large areas of protected state, federal, and conservation lands north and south of I-90 support a broad range of habitats and a diverse array of plants and wildlife. Since the late 1990s, the area has been managed according to the Snoqualmie Pass Adaptive Management Area 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 five years. These land purchases, along with the I-90 Land Exchange, have added 75,000 acres (approximately 117 square miles) of land to the National Forest system adjacent to and within the I-90 Project area (2).
Even with conservation efforts, I-90’s presence limits wildlife movement and forms a physical barrier between upstream and downstream aquatic environments. Existing culverts and narrow bridges limit aquatic species movement, and in many cases, the highway embankment has filled in habitat that once made up channels, floodplains, and associated wetlands (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.

The last major road construction on I-90 Snoqualmie Pass began in the 1950s when President Dwight D. Eisenhower signed the Federal-Aid Highway Act of 1956, which started the construction of Interstate Highways; construction was completed in the 1970s. Since the 1970s, the state’s transportation needs for I-90 over Snoqualmie Pass have changed, and the existing roadway has deteriorated.

Today, daily traffic on Snoqualmie Pass averages about 27,000 vehicles, typically 22,400 passenger vehicles and 4,600 freight vehicles. Traffic volumes can rise to more than 59,000 vehicles on weekends and holidays. According to WSDOT traffic studies, travel across Snoqualmie Pass is growing at an annual rate of 2.1 percent, with 51,000 vehicles projected to use I-90 daily by 2028.

IDENTIFYING A PROJECT PURPOSE AND NEED

Seeing a need for additional highway capacity and safety improvements, WSDOT began the public scoping process for the I-90 Project in 1999. By 2000, an Interdisciplinary Team (IDT) was formed consisting of representatives from WSDOT, the Federal Highways Administration (FHWA), USFS, Environmental Protection Agency (EPA), USFWS, and Washington Department of Fish and Wildlife (WDFW); advisory agencies included Washington State Parks, U.S. Army Corps of Engineers, and Washington Department of Ecology (Ecology). The IDT was formed to begin preliminary engineering and environmental analysis of the project area. Additional teams were formed, including a Mitigation Development Team consisting of biologists and hydrologists from WSDOT, USFS, USFWS, and WDFW, and a Wetlands Mitigation Technical Committee consisting of a GIS specialist, biologist, and environmental planner, to conduct further environmental analyses and provide design recommendations.

After five years of corridor analysis, WSDOT published the I-90 Snoqualmie Pass East Project Draft Environmental Impact Statement (Draft EIS) for public review and comment in 2005. The Draft EIS highlighted six build alternatives that could potentially meet the project’s identified purpose and need for:

- Reducing the risks of avalanche to the traveling public and eliminating road closures required for avalanche control work,
- Reducing the risk of rock and debris falling onto the roadway from unstable slopes,
- Fixing roadway structural deficiencies by replacing damaged pavement,
- Providing for the growth-related increases in traffic volume, and
- Connecting habitat across I-90 for fish and wildlife (3).

Over the next two years, WSDOT continued using existing partnerships and formed new teams, including a Stormwater Technical Committee and Wildlife Monitoring Technical Committee to help advance technical investigations and identify a preferred design alternative for the I-90 Project. These collaborative efforts culminated with the release of the Final EIS in August 2008 that identified WSDOT’s preferred design alternative for the I-90 Project. FHWA issued its Record of Decision concurring with WSDOT’s preferred alternative in October 2008, which paved the way to complete final design and for construction to begin.

DEVELOPING I-90 PROJECT DESIGN CONCEPTS

After identifying the I-90 Project Preferred Alternative, project engineers began working with the IDT, Mitigation Team, and Wetlands Committee to develop conceptual design plans for ecological connectivity structures.

The Mitigation Team presented design engineers with scientific information and site-specific technical report data that determined the existing ecological conditions within the project area. This data identified 14 north-south ecological linkage areas, or Connectivity Emphasis Areas (CEAs), within the
project area that provided the highest benefit-to-cost ratio and long-term solutions to the issue of ecological connectivity (see figure 2).

FIGURE 2 15-mile project corridor north-south ecological linkages
Figure 2 shows identified CEAs and the bridges and culverts (in yellow) that will be placed at each CEA to improve connectivity.

Each CEA provided an opportunity to improve connectivity for a unique assemblage of species. CEAs ranged in complexity from single stream crossings to multiple stream crossings with associated wetlands and areas of diffused surface flow, to upland areas that were important travel corridors for wildlife (2). The Mitigation Team found that crossing structures would be more effective for some species if they contained habitat, rather than simply being physical connections between habitats on opposite sides of the highway. For instance, lower mobility animals would feel more secure crossing a structure if it contained hiding cover. Different animals show different preferences for crossing structures, whether the structures are small, medium, or large (2).

After analyzing all of the Mitigation Team’s recommendations, WSDOT engineers and the Mitigation Team collaborated to develop conceptual designs for the highway alignment, drainage plans, staging and construction requirements, traffic control strategies, and initial bridge plans at each CEA. The design team also continued to develop designs independently.

While working with the Mitigation Team and technical committee, WSDOT and consultant engineers were also gathering geotechnical data from extensive drilling operations on the mountain slopes, in the lakebed of Keechelus Lake, and along the existing roadway to determine geological conditions. This data was essential to progressing conceptual CEA designs.

Geotechnical findings indicated that certain portions of the project area contained stable rock and favorable sediment, while other areas contained soft frangible rock and liquefiable soil conditions. Since liquefiable soil conditions result in global instability of structure foundations, WSDOT engineers had to rethink how to construct certain CEA concepts (bridges and culverts). Engineers worked to improve conditions and meet seismic regulations while still aligning with Mitigation Team and Wetlands Committee recommendations. In addition to seismic issues, WSDOT engineers had to reformat other CEA designs to address other unforeseen issues pertaining to erosion, stormwater treatment, clearance, and constructability. These design changes had to be made in a way that minimized footprint impacts, prevented wetland impacts, considered endangered species in the area, and preserved archeological, cultural, and recreational resources.

In the following sections, case studies will explain how WSDOT I-90 Project engineers modified original design concepts to resolve conflicts between ecological connectivity recommendations and objectives and the unforeseen seismic, erosion, stormwater treatment, clearance, constructability, and other resource issues.
IMPROVING GROUND CONDITIONS AT GOLD CREEK CEA WITHOUT IMPACTS TO WETLANDS, ENDANGERED SPECIES, AND FOOTPRINT

An important CEA identified by the Mitigation Team is located near the Gold Creek Valley. The Gold Creek CEA is located between milepost 55.2 and milepost 55.8, near the starting point of the I-90 Project. 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 (2).

To be successful at meeting objectives, WSDOT and the Mitigation Team determined a high level of connectivity for the high- and low-mobility species associated with the mountain hemlock-subalpine fir forests, riparian habitats, wetlands, and floodplains must be provided year-round. Other objectives for this CEA include:

- Providing a high level of connectivity across the reservoir bed for approximately nine to 10 months of the year. (The Keechelus Lake reservoir inundates the lakebed at high pool during late spring.)
- Significantly reducing wildlife / vehicle accidents in this high road-kill zone for deer and elk. This will require wildlife fencing around the crossing structures.
- Restoring natural channel migration processes and reducing floodplain confinement, particularly upstream of I-90 where floodplains and associated wetlands are not inundated by Keechelus Lake; restoring capacity to convey flood flows, sediment, and debris through the Gold Creek crossing structure.
- Providing fish passage and habitat improvements for threatened bull trout for the full range of lake elevations.
- Improving water quality by properly treating stormwater and highway runoff, and minimizing de-icer chemical use.

The initial Gold Creek CEA concept recommended by the IDT and accepted by WSDOT was to replace the existing 138- and 126-foot bridges with a 1,200-foot eastbound bridge and a 1,000-foot westbound bridge (2). This would provide a connection through the highway for approximately nine to 10 months a year. Additional clearance for winter snowpack was also recommended.

After identifying objectives and conceptual Gold Creek CEA bridge designs, WSDOT conducted geotechnical drilling at the Gold Creek area. Geotechnical findings indicated areas of liquefiable soil conditions at the Gold Creek CEA site. Liquefiable soils (typically saturated sand) are a concern because during an earthquake, the soil looses shear strength and can flow like a liquid. This results in global foundation stability issues with bridge designs. To construct the bridges and meet seismic code requirements, WSDOT engineers would need to stabilize ground conditions.

Engineers originally proposed to improve liquefiable soils with a technique known as bottom-fed vibro-replacement stone columns. The stone columns were to range in diameter from 2.5 feet to 3.5 feet and would be constructed on a grid pattern designed to suit the load, soil, and performance types. Column holes were to be bored at varying design depths of approximately 50 feet deep in places, then dense, angular crushed or shot rock backfill would be introduced in discrete lifts from the ground surface. Re-penetration of each lift would compact the stone in the surrounding soil. Once complete, the replacement stone columns would have effectively reduced foundation settlement, mitigated liquefaction potential, improved shear resistance, and increased bearing capacity.

The ecological impacts of the vibro-replacement ground stabilization technique, however, raised red flags among partnering resource agencies. Partners were concerned that construction of the stone columns would temporarily and permanently impact wetlands and expand the footprint of the roadway prism. This technique would require a pattern of stone columns roughly 50 feet beyond the toe of the highway embankment, necessitating construction within adjacent wetlands.
Understanding the importance of addressing resource agency concerns, WSDOT design engineers developed a list of plausible alternatives for improving the soil conditions at Gold Creek. WSDOT presented these alternatives to its partners, and together, determined an acceptable method of improving ground conditions that met both transportation and ecological connectivity objectives.

The new, agreed-upon method of improving the liquefiable soils is compaction grouting. A very viscous (low-mobility), aggregate grout will be pumped in stages, starting up to 50 feet deep in places and working toward the ground surface. The grout will form a column of bulbs, which densifies and displaces the surrounding soils. WSDOT will construct the grout columns on a grid pattern designed to suit load, soil, and seismic performance. Once complete, the grout columns will reduce foundation settlement, mitigate liquefaction potential, improve shear resistance, and increase bearing capacity. This technique uses a much smaller pattern (20-feet by 30-feet in total), localizes impacts to directly beneath the embankment fill area next to the bridge abutment, and allows minimization of the highway footprint.

ELIMINATING SCOUR ISSUES AT GOLD CREEK BRIDGES WHILE MAXIMIZING THE RESTORATION AREA

The Gold Creek CEA serves as a wildlife crossing structure, restores natural channel migration processes, and reduces floodplain confinement. Because of high spring flows within the creek, WSDOT engineers had to plan for scour in their bridge designs. Original bridge designs called for optimizing costs by keeping the foundations shallow - above ground water level - and using “launching toe” revetments consisting of large rip-rap to protect the foundation embankments (see figure 3).

The height and width of the planned revetments, however, resulted in a conflict with CEA objectives. Partnering resource agencies were concerned revetments would reduce clearance and openness, limit the amount of re-vegetation that could occur, and reduce the amount of available wetland credit for the restoration area under the bridges.

WSDOT design engineers and the resource agencies collaborated on finding a new design that would satisfy CEA objectives and scour mitigation costs. The resulting compromise in design called for lowering the armament to just below ground level, thereby enabling re-vegetation and openness of the area. Bridge foundations will be accompanied by large rocks inserted under ground, near the scour level at the toe of the bridge (see figure 3).
CREATING A HABITAT CONNECTION AT GOLD CREEK CEA/UPPER KEECHELUS LAKE, WHILE TREATING STORMWATER AND REDUCING WETLAND IMPACTS

The I-90 Project corridor passes through the Wenatchee National Forest and runs adjacent to the north eastern shore of Keechelus Lake for the first six miles, then parallels the Yakima River for the remaining nine miles. The project crosses five tributaries to Keechelus Lake and nine significant tributaries to the Yakima River, including the Kachess River. The project also crosses or is adjacent to numerous wetlands (4). Therefore, incorporating stormwater management systems into I-90 Project is essential for minimizing contamination of terrestrial and aquatic habitats. Stormwater treatment facilities also present WSDOT with the opportunity to repair water quality problems caused by the existing highway. For example, in certain creeks located within the project area, water quality has been effected due in part, to sediment (traction sand from both I-90 and the adjacent WSDOT Maintenance facility sandpile), and the presence of metals (lead and arsenic) in stormwater runoff.

The selection, design, and mitigation process for this stormwater system is complex. Portions of the project are located on steep slopes (rock cliffs) where construction of Stormwater Best Management Practices (BMPs) would be very difficult and require extensive structural support. Other typical freeway BMPs such as infiltration swales and ditches are infeasible because portions of the project are located in narrow corridors where cliffs are on one side of the freeway, and a lake or river is on the other side, with no room for a median. And while not exactly a physical constraint, snow management and snow hydrology plays a large role in how space is utilized and what BMPs are most suitable, with open areas in the median or adjacent to the freeway likely doubling as both snow storage areas as well as stormwater BMP locations (4).

To help identify issues and find the best solutions to solve stormwater treatment challenges, WSDOT created a multi-agency Stormwater Technical Committee to review stormwater technical and
permitting issues; evaluate mitigation approaches developed by WSDOT; and recommend appropriate, effective, and efficient mitigation methods to the design team. Committee members included WSDOT and consultants, USFS, and EPA staff that have permitting approval roles or are partner agencies with a strong interest in helping solve stormwater problems.

WSDOT and the Stormwater Committee conducted several in-depth studies and determined that a stormwater treatment and snow storage facility was needed near the Gold Creek CEA. The identified preferred location for the facility was at the WSDOT Maintenance facility, just west of the Gold Creek CEA, where additional upland habitat was being created to enhance the effectiveness of a planned undercrossing. WSDOT engineers believed they could further enhance the Gold Creek CEA’s effectiveness by reducing visibility and noise of the stormwater treatment facility and reducing noise from the maintenance facility by building a separation between the two areas.

Plans originally called for using a wide grassy swale to treat stormwater from the maintenance facility and building of a tall berm at the upland below the undercrossing to reduce light and noise. Engineers also planned for snow storage within the grassy swale.

As designs progressed, however, resource agencies expressed concerns over the footprint of the Keechelus Lake bench design and its impact to the wetland. But because so many transportation facility design objectives and ecological objectives needed to be met at this one location, all parties had to compromise on design. To reach compromises, several organized meetings were held among engineers, technical committees, and resource agencies. In the end, WSDOT compromised for less snow storage space and a more compact stormwater BMP with higher maintenance requirements. The resource agencies compromised by allowing minor wetland and footprint impacts through a shorter, vegetated berm and reduced upland area, versus the previous taller bench design. WSDOT will add vegetation - tall trees - to the shorter and smaller berm design to make up the reduced structure height (see figure 4).
Figure 4 shows the conceptual plans for lowering the berm and vegetating it with tall trees to reduce noise and visibility of the stormwater treatment facility.

Other Stormwater Treatment Design Challenges
Further challenges arose when designing other stormwater treatment facilities for the I-90 Project. Since the project corridor is constrained for most treatment options, Media Filter Drains (MFDs) were selected and approved by Ecology as the most viable treatment option for use along the corridor. MFD’s are linear flow-through stormwater treatment BMPs that can be placed along a highway shoulder for the treatment of sheet flow runoff generated from the highway pavement. MFD’s remove suspended solids, phosphorus, and metals from highway runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration.

MFDs as approved by Ecology, however, are not inline with USFS invasive species guidelines since they do not allow for vegetated plantings. While WSDOT has engaged in a pilot program to test growing vegetation on MFDs elsewhere in the state, the pilot program is still underway and vegetated MFDs are still considered experimental. WSDOT sought and obtained approval for use of a vegetated MFD on Snoqualmie Pass in order to meet USFS objectives.

ELIMINATING SCOUR ISSUES AT WOLFE CREEK CEA WHILE ENHANCING WILDLIFE AND AQUATIC MOBILITY
The Wolfe Creek CEA is located between milepost 57.1 and milepost 57.3. The forest habitat adjacent to this CEA is the Western Hemlock Series, grading into the 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 (2).

Currently, Wolfe Creek passes under I-90 in a 6-foot box culvert and empties into the east side of Keechelus Lake. The Mitigation Team recommended that WSDOT construct a 25-foot by 8-foot bottomless culvert westbound and a 20-foot by 10-foot bottomless culvert eastbound to meet the connectivity needs of wildlife and aquatic organisms, while passing flood flows and debris. This conceptual bridge would need to meet WDFW stream requirements for fish bearing streams.

As engineering designs progressed at this CEA, hydrologic analysis identified scour issues from the high-velocity, steep gradient stream that could undermine the culvert foundations and walls. WSDOT engineers considered using larger foundations for the bottomless culvert design, but the larger, deeper foundations were costlier and generated additional construction impacts to the creek banks and / or wetlands. Engineers also explored bridge options, versus a culvert, but again, foundation and cost issues proved formidable challenges.

Design engineers, working with WDFW, developed an alternative that included a four-sided box culvert with a stream-simulated bottom. The stream-simulated bottom, a standard WSDOT practice, was designed deep enough to hold four feet of stream-simulation material and maintain the eight feet of clearance needed to meet Mitigation Team recommendations. WSDOT presented this design option to resource agencies, and after thorough review, the agencies agreed that the four-sided box culvert design would provide a high-level of protection for the roadway against scour and still meet the connectivity objectives of restoring capacity for flood and debris flow, providing fish passage for the full range of lake elevations, and providing aquatic organism connectivity.

DESIGNING ROCKY RUN BRIDGES FOR CLEARANCE AND CONNECTING HABITAT
The Rocky Run Creek CEA is located between milepost 56.7 and milepost 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 the 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 Mitigation Team recommended that WSDOT improve connectivity in
this area by building twin 120-foot bridges to meet the needs of wildlife and aquatic organisms, while passing flood flows and debris (2).

The challenge for WSDOT engineers was to design the Mitigation Team-recommended bridges to optimize clearance beneath the bridges for openness of habitat while keeping the footprint of the highway small to avoid impacts to Keechelus Lake. WSDOT engineers wanted to achieve clearance of at least 16-feet for each Rocky Run bridge to account for snow pack. Varying topography and road profiles between the separated eastbound and westbound lanes at Rocky Run Creek however, would not allow engineers to achieve the clearance needed without further elevating the road profile and increasing the highway footprint. Elevating the profile, however, would not meet design standards for design speeds and also presented safety considerations. To elevate the road profile, engineers would have to create a large crest in the road, creating visibility issues and impacting other resources by enlarging the footprint.

WSDOT engineers decided to go back to the drawing board for the Rocky Run Creek bridge designs. Engineers first determined that the new I-90 road profile at Rocky Run Creek needed to be built at the same elevation for both eastbound and westbound lanes across the separated highway to minimize footprint. Engineers also determined that the only way to keep the consistent elevation levels across the bridges, while adding habitat benches under the bridges for connectivity purposes, was to compromise bridge clearance on the westbound structure. The resulting design called for a westbound bridge with reduced clearance and an eastbound bridge with greater clearance (see figure 5). The eastbound bridge was also lengthened to accommodate longer fill slopes and keep some habitat along the creek.

![FIGURE 5 Rocky Run bridges](image)

Figure 5 shows a design visualization for the Rocky Run CEA.

WSDOT engineers successfully overcame design challenges at Rocky Run Creek with new designs that achieved the connectivity objectives of providing moderate level connectivity for high- and low-mobility species associated with the mountain hemlock / subalpine fir species assemblage zone, restoring capacity for flood and debris flow at the crossing structure, and providing fish passage for the full range of lake elevations.

**Subsequent Rocky Run Issue Regarding Profile Adjustment**

After determining the best profile for the highway to meet clearance and footprint objectives at Rocky Run Creek, archeological and cultural conflicts arose with a USFS Service Road. By elevating the highway profile to create clearance at the creek bridges, the USFS Service Road adjacent to I-90 would become lower than the adjacent interstate, resulting in possible embankment encroachment. WSDOT proposed to raise the profile of the USFS Service Road to remedy the problem, but this would require
WSDOT to disturb an adjacent property containing old growth trees and a structure eligible for the National Historic Register and State Historic Preservation Office resources. Since not many compromises were available to reduce the primary and secondary impacts of the situation, WSDOT engineers accepted that designing around this issue would require additional cost. WSDOT moved forward with plans to raise the profile of the USFS Service Road and reduce impacts to the historic property by adding a small system of precast concrete barrier to retain the existing slope. WSDOT also re-routed planned drainage systems in the area to lessen the impact near the historic site.

CONSTRUCTABILITY AND FLOODPLAIN ISSUES OF RESORT CREEK CEA
The Resort Creek CEA is located between milepost 59.3 and milepost 59.7. 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 (2). The Mitigation Team recommended that WSDOT install a series of bottomless culverts 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. The series of culverts would allow the creek channel to shift location across the alluvial fan in response to sediment deposition and debris blockage. Culverts would be sized to meet WDFW stream simulation requirements for fish passage.

As WSDOT engineers advanced this design, uncertainty emerged about Resort Creek actually meandering across the alluvial fan. Additionally, the costs to install a temporary shoring system in order to construct the bottomless culverts and maintain traffic through the construction zone were exorbitant. WSDOT engineers reformulated designs by replacing the culverts with a 180-foot-long bridge that not only provided a large opening across the floodplain for natural creek function, but also created a better wildlife crossing structure for aquatic and terrestrial species.

WSDOT engineers presented this modified design to the IDT and Mitigation Team. The agencies agreed that this option achieved connectivity objectives – reducing wildlife / vehicle collisions, restoring capacity for flood and debris flow, providing fish passage, and restoring habitat / aquatic connectivity and channel migration – while meeting the additional objective of providing connectivity for large and small species.

MOVING DESIGN PLANS FORWARD AND PREPARING FOR CONSTRUCTION
After years of working with project partners and resource agencies to find viable solutions to competing objectives between transportation facility design and ecological connectivity, WSDOT engineers are finalizing the remaining design plans and preparing for construction of the second and third construction contracts.

The funded five-mile portion of the I-90 Project from Hyak to Keechelus Dam has been broken into three construction contracts. Design and construction of the first construction contract – Phase 1A - are complete. Construction of Phase 1A began in July 2009 and was complete November 2009. WSDOT built a long-term detour bridge at Gold Creek for use in the second construction contract of the project and mitigated for future lake storage impacts to Keechelus Lake – an irrigation reservoir – by excavating approximately 260,000 cubic yards of material from the lakebed. WSDOT has committed to a no-net-loss agreement with U.S. Bureau of Reclamation to not affect lake storage capacity during construction of the I-90 Project.

WSDOT completed designs and permits for the second construction contract – Phase 1B – in fall 2009, with a Nov. 2, 2009 contract advertisement date. This contract calls for replacing the deteriorated concrete pavement of the existing four lanes, adding a new lane in each direction, rebuilding bridges and culverts, stabilizing rock slopes, and extending chain up / off areas along the first three miles of the project. WSDOT expects to begin construction of Phase 1B in spring 2010.
Engineering designs and permitting actions are still underway for the third construction contract – Phase 1C – that will cover the remaining two project miles. Phase 1C calls for replacing deteriorated concrete pavement, adding a new lane in each direction, replacing the existing snowshed, addressing unstable slopes, and building new bridges. Phase 1C is expected to advertise to contractors in fall 2010, with construction scheduled to begin in spring 2011. All I-90 Hyak to Keechelus Dam Project improvements are scheduled for completion in 2015.

To move the remaining Phase 1 design plans forward, engineers are finishing geotechnical drilling on the rock cliffs and lakebed along the I-90 Project corridor. Drilling core samples will help identify structural needs for the snowshed and the potentially unstable slopes along the corridor that will require stabilization measures as the rock cuts are excavated. WSDOT will stabilize slopes with grouted steel bars that are designed in accordance with the structural geology and height of each rock cut. WSDOT and a consultant team of geologists are also conducting geophysical studies using downhole surveys for bedrock mapping to identify terrain conditions and design the highway realignment.

Other work includes completing the structural designs for the remaining three CEAs, roadway drainage, and the new snowshed, which also includes mechanical system designs for illumination, ventilation, back-up electrical generation, and Intelligent Transportation Systems (ITS). Engineers are also finalizing construction schedules and other logistics for traffic control and staging.

Pre-construction wildlife monitoring activities continue to move forward as well. As part of the I-90 Project Wildlife Monitoring Plan, WSDOT and its partners are evaluating the locations and rate of wildlife / vehicle collisions; assessing the use and effectiveness of wildlife crossing structures – both existing and planned; characterizing the locations and rate of at-grade highway crossings by wildlife; estimating species occurrence and distribution in the project area; assessing the effectiveness of fencing; and appraising the effectiveness of jump-outs (5). Methods being used to meet pre-construction objectives include assessing wildlife use of existing culverts and underpasses via remote cameras; documenting crossing rates via snow tracking; evaluating the distribution of various target species via both noninvasive survey methods and live-capture; and documenting wildlife-vehicle collisions. In addition, specific projects to monitor low-mobility species such as fish, amphibians, and pikas have been initiated.

Wildlife monitoring efforts will continue during and after construction of the I-90 Project. The engineering team is working to ensure successful post-construction monitoring efforts by integrating communication systems into the infrastructure of the highway. Engineers plan to install fiber-optic communication cables at each CEA that will instantly transmit wildlife usage data, including images, to WSDOT for more efficient collection of information. Engineers would also like to make the live feeds available for public viewing on the WSDOT Web site.

The engineering team continues to test various prototypes of wildlife exclusionary fencing to find a design that will withstand winter weather conditions, maintenance operations, and redirect wildlife away from the interstate and to crossing structures. Several prototypes have been tested over the last two winter seasons; engineers are hopeful to finalize fencing plans this year.

CONTINUING COLLABORATION TO RESOLVE FUTURE ISSUES

Open and honest communication, and the desire to establish and engage in partnerships early on, is what inevitably allowed WSDOT to develop consensus for a long-term vision for the I-90 corridor. By sharing ideas, being adaptive in designs, and receptive to compromises, WSDOT and its partners have designed a project that will not only improve the safety and reliability of a vital cross-state corridor, but will also promote the continued health of the delicate ecosystems of the Central Cascades for generations to come.

WSDOT will continue to collaborate with project partners, stakeholders, and resource agencies to overcome challenges as they arise during construction and in future designs. While the remaining 10 project miles from Keechelus Dam to Easton remain unfunded at this time, WSDOT, along with its project partners, stand ready to deliver.
REFERENCES


