An Ecological Perspective on Gold Creek Valley: Biology, History, and Potential for Restoration

Jim Evans, June 2021 (edited and links updated, January 2024)

Contents

1. Introduction

This document offers an ecological interpretation of the history, human impacts, current condition, and potential for restoration in Gold Creek Valley, based on scientific literature and historical documents. Additional goals include clarifying what 'ecological restoration' is and isn't, and the use of important tools and technologies, in particular engineered log jams, in river habitat improvement and the protection of human infrastructure. The key points are as follows:

- There is no doubt among biologists that **healthy riparian ecosystems** – the complex, interrelated ecosystems made up of a river or creek, the groundwater, and the associated streambank and floodplain plant communities **– support more wildlife, more biological diversity, than any other kind of habitat in the Cascades, throughout Washington, and almost everywhere on earth.** Although the Gold Creek ecosystem holds the promise of being able to function at a high level for wildlife, in its current condition it offers only a fraction of the resources it once did (Section 2).
- In a larger context, **there is a consensus among the world's scientists that wildlife in North America and around the globe** – from the tiny things that escape our notice to the largest mammals – **have had so much of their habitat converted to other uses or rendered inhospitable that even common species are exhibiting significant declines in their populations almost everywhere.** Plain old habitat loss is responsible for most of the declines seen up to now, but climate change is increasingly adding stress to populations that are already stretched thin. **Wildlife desperately need projects that repair damage to the ecosystems they depend on. Without human intervention these trends are only expected to get worse** (Section 2 and Appendix B).
- **Logging, gravel mining, and other historical practices have significantly reduced Gold Creek Valley's capacity to support wildlife.** Like many of our mountain environments, the Gold Creek Valley ecosystem has been significantly changed by human activities, in particular by intensive logging along the stream and floodplain and by large-scale gravel mining in the stream channel itself and across the floodplain, as well as by other factors. The unintended consequences of these historical activities are still with us today in the form of the over-widened and dewatered reaches of lower Gold Creek, in the lack of large wood and the resulting simplified habitat structure in the stream channel, in the depleted and underproductive riparian vegetation, and in altered groundwater flow. There's no question that these major impacts to these fundamental habitat features have severely diminished the Valley's ability to support aquatic and terrestrial wildlife**. The Endangered Species Act focuses attention on rare species like bull trout, but nearly *all* species in the Valley ecosystem are affected by this loss of habitat** (Section 6 and Appendices A and D).
- **The goal of ecological restoration is not to make a place *look* like it once did but to help a damaged ecosystem to *work* as it once did, as much as possible, for all the services that it can provide for wildlife and for people.** Restoration of the stream channel, riparian vegetation, and supportive surface and groundwater hydrology of Gold Creek promises to elevate the productivity and biological carrying capacity – how many animals the landscape can support – of the entire Valley ecosystem. **Restoration would increase the resilience of the Valley ecosystem to climate change** and contribute to its being part of a network of mid-elevation refuges and migration routes in the Cascades

that would benefit many species of wildlife at a time when it is increasingly essential for their survival (Sections 3 and 4 and Appendix C).

- **Gold Creek Valley is not an interchangeable part. It is an irreplaceable connection in a regionally significant north-south wildlife passage between the largest continuous extents of mostly undeveloped, *publicly owned* land in Washington.** Wildlife will need unimpeded access to every bit of this diverse landscape in order to cope as well as possible with continuing habitat loss elsewhere and with the mounting stresses of climate warming. Scientific analyses identified Gold Creek Valley as a critical migration corridor for wildlife, linking areas of this landscape separated by the barrier of I-90, which is why our state has invested in state-of-the-art wildlife bridges at the mouth of the Valley. But degraded, underproductive habitat, as in Gold Creek Valley today, presents another kind of barrier to wildlife, especially for smaller, less mobile species. Improving habitat quality – or carrying capacity – in Gold Creek Valley is vitally important to fully realize the function of those wildlife bridges as quickly as possible (Section 3).
- **Gold Creek Pond is not a natural, productive habitat. Its banks are too steep and its water is too deep to support most wetland wildlife.** Plants are the foundations of all food chains or food webs. The species-specific tolerances of wetland plants for waterlogged soil and water depth determine the vegetation structure of wetlands and, therefore, the wildlife-habitat relationships within a wetland. Natural valley floor wetlands typically have shallow slopes and shallow standing water, favoring the greatest diversity of vegetation and the wildlife it supports. Human-made features such as Gold Creek Pond, with steep slopes and water depths plunging to over 50 feet deep severely limit the area that wetland plants can colonize and therefore greatly limit the biological productivity and wildlife habitat value that feature can offer (Section 5).
- **Analyses by numerous public agencies and private conservation organizations agree that the Gold Creek Valley ecosystem is among the top priority areas for conservation and restoration in the upper Yakima River basin.** The science of ecological restoration has developed and tested tools, including engineering technologies, to direct damaged river and stream ecosystems, towards greater productivity, habitat value, and long-term resilience (Sections 4 and 7, and Appendix E).

The complexity of ecosystems and their responses to historical events like those in Gold Creek Valley require us to consider as complete an environmental context and land use history as we can if we want to understand as fully as possible both the causes and the available remedies for environmental problems. I've tried to convey the essential elements of Gold Creek's ecological story, as I understand it from available evidence, as plainly and concisely as possible and without leaving out important elements. I'm sure it's not perfect, but I'm also sure it provides valuable context and information that can be missing from our community discussions. Constructive feedback, additional evidence, questions and clarifications are welcome from anyone and everyone. An evidence-based discussion can only contribute positively to our community's understanding about the Valley and our place in it.

SOURCES OF INFORMATION

Genuine evidence can be checked and verified. The sources of information in this document are identified in the text by superscript numbers and listed sequentially in the End Notes beginning on page 68. Scientific information is primarily from peer-reviewed scientific journal articles and authoritative reports by respected professionals. Many of these sources are review articles, state-of-our-knowledge papers crafted by eminent scientists based on a distillation of dozens or hundreds of original research papers. Many of these sources are available free on the Internet, and wherever possible I've furnished links so people can see for themselves. All Internet links were checked and verified as of January 2024.

2. The Importance of Riparian Areas to Wildlife of the Cascades Ecosystem

"Protecting riparian habitat may yield the greatest gains for fish and wildlife across the landscape while involving the least amount of area."

K. Lea Knutson and Virginia Naef. Management Recommendations for Washington's Priority Habitats: Riparian (1997).[1]

Gold Creek, like any other natural stream system, is part of a complex system of interacting physical and biological elements known as a riparian ecosystem. A riparian ecosystem is made up of the active stream channel, the hyporheic zone (shallow groundwater under and around the stream channel), the streambank, the active floodplain and associated wetlands, and former floodplain terraces that contribute matter and energy to the system, and is strongly influenced by local groundwater.[2] **Acre for acre, riparian areas provide habitat for more wildlife than any other part of the landscape.** Some wildlife species may be found *only* in riparian areas, but an extraordinary number – some 85% of Washington's wildlife species today – count on these habitats at one time or another for essential life activities.[1,3,4,5]

Together, healthy streams and riparian areas harbor so many kinds of life it would be difficult to try to list them all: Fish of many kinds (from small sculpins to salmon and trout); terrestrial and aquatic insects, tiny organisms we never see but which are always at work; mammals large and small, predators and prey, producers, consumers, and decomposers, all bound together in webs of interaction made possible by the rich, complex habitat features concentrated in the riparian and floodplain areas along rivers and streams.[1,3,6] More than 80% of Washington and Oregon's non-marine bird species breed in riparian habitats and long-distance migrants such as warblers, thrushes, flycatchers, and others (many of which are in serious decline[7,8]) depend on riparian areas during migration for the abundance of seeds, insects, and other critical resources these areas produce.[3,6,9]

Healthy riparian ecosystems are able to contribute so much to wildlife diversity and abundance because topography, river dynamics, and their position in the landscape combine to concentrate resources and habitat features in these places more than anywhere else on the broader landscape.[3,10] Characteristics that give these places such a high carrying-capacity for wildlife include:

- High plant species diversity and high plant productivity compared to the surrounding landscape.
- A high degree of habitat complexity (the mix of vegetation and physical habitat features).
- Access to the resources of both aquatic and upland habitats close by to each other.
- The availability of long-distance connections to other ecosystems, habitat types, and populations made possible by the natural configuration of stream and riparian networks themselves.[1,3,10,11,12,13]

Ecological carrying capacity:

The maximum number of species and individual animals that can be sustained by that a specific habitat or ecosystem, given the available food, water, structural characteristics and other resources.

The fate of bull trout in Gold Creek is *only one of many reasons* why conservation-minded people would consider strategies to restore the Gold Creek Valley ecosystem. Because of their capacity to support more wildlife in less area, riparian ecosystems are among the most strategic places to focus conservation and restoration efforts. And while the legal mandates of the Endangered Species Act are influential drivers of conservation initiatives and funding, defining the success of potential restoration efforts in Gold Creek Valley in terms of just a single species overlooks the opportunity to address the overall degraded condition of the Valley ecosystem and all the species that condition affects (see Appendix A). It overlooks the importance of healthy stream and riparian areas to almost *every* kind of fish and wildlife in the Cascades and how a degraded system can supply only a diminished portion of their vital needs. It overlooks the role mid-elevation ecosystems like Gold Creek Valley must play as refuges and migration routes for wildlife already confronted with extreme habitat loss and now facing global warming. Most significantly, it fails to recognize the regional and global background against which restoration proposals have to be weighed in the 21st Century, which is that our ecosystems are in danger of fracturing and that populations of even common wildlife species are facing existential threats due to extreme habitat loss and a host of other human-related stresses. This is not one person's anxiety; it's a mounting and documented consensus of the world's leading conservation scientists. If you think it can't be as bad as all that, please see **Appendix B. Pacific Northwest and Global Wildlife in Peril in the 21st Century**. It's not a pretty picture, but we have to learn about it if we're going to do anything about it.

To address these mounting challenges, conservation and restoration projects are increasingly designed to protect or restore the ecosystem processes and habitat characteristics that function to support a full complement of wildlife and build climate-resilient landscapes, rather than focus on the recovery of a single species.[3,14] And although public funding sources may specify that funding must be used to recover endangered species, every habitat biologist knows that **restoring the healthy stream and riparian habitats that salmon and trout require turns out to be restoring prime habitat for nearly every other species across the landscape as well**.

Sadly, Gold Creek can no longer check many of the boxes on the habitat quality checklist that it once could. The creek's over-widened channel leaves riparian vegetation far from the water that should be driving its productivity, distant even when the creek is flowing. The riparian vegetation is hardly engaged with the stream. There is virtually no shade to keep water from heating up in the summer sun, to moderate evaporation, or to provide cover for fish and other animals. When trees and shrubs are so far from the stream, scant leaf litter and other organic matter – material produced by riparian vegetation that should be captured, retained, and cycled through the creek as a foundation of the aquatic food web – make it into the aquatic system at all. A vegetated riparian corridor functions as a pathway for short and long wildlife movements because of its rich resources, moderate microclimate, cover, and other favorable factors. These are lacking in and along the lower Gold Creek we see today, replaced instead by an inhospitable rockery during the very months when a healthy, productive stream corridor would provide wildlife the greatest benefit. Because stream and riparian corridors are focal use areas for wildlife from across the landscape, these limitations on the habitat quality of Gold Creek affect the carrying capacity – the ecological vibrancy – of the entire Valley and beyond.[15,16]

Gold Creek is not a wasteland – I never visit the Valley without experiencing wonder at some aspect of the life there – but it is substantially diminished from the fully functioning ecosystem it once was. Healthy riparian ecosystems are sites of extraordinary vitalityas well as places of wonder and discovery. In this time of global warming, Gold Creek needs all of its moving parts to be in the best order possible, because wildlife will need it to be one of their lifeboats to the future. And Gold Creek holds that promise.

3. The Keystone Role of Riparian Areas in the Era of Climate Change

"Functional riparian systems have tremendous potential to reduce the adverse effects of climate change by enhancing ecosystem resilience."

Nathaniel Seavy, Ph.D., University of California Center for the Environment.
Why climate change makes riparian restoration more important than ever:
Recommendations for practice and research (2009). *Ecological Restoration* 27:330-338.[17]

"Past land uses … have often degraded habitats to a greater degree than that predicted from climate change, presenting substantial opportunities to improve salmon habitats more than enough to compensate for expected climate change effects over the next several decades."

Tim Beechie, Ph.D., NOAA Northwest Fisheries Science Center, Seattle.
Restoring salmon habitat for a changing climate (2013). *River Research and Applications* 29: 939–960.[16]

Wildlife populations are already suffering large-scale population declines due to habitat loss and other factors associated with human practices (see Appendix B). Global warming adds new stresses as it increasingly disrupts the remaining habitats that wildlife has relied on up to now. It is clear that if we want and expect to preserve anything resembling the wildlife populations we are familiar with today, the scientific consensus is that we will have to redouble our efforts to protect and restore the ecosystems wildlife depend on and build as much climate resilience as possible into our landscapes.

Far from interpreting climate change as a reason to back away from restoration projects, conservation scientists and habitat professionals interpret the climate threat as making restoration -- and restoration of stream and riparian areas in particular -- more important than ever. Riparian areas have a greater capacity to support the needs of a wide array of wildlife in a warming world than nearly any other habitat type.[17] And Gold Creek Valley holds this promise.

Reasons why healthy riparian areas are so important for climate resilience include the following:

Stream and riparian systems are naturally resilient. Healthy rivers and streams are constantly changing: flooding, moving, eroding one surface here and depositing that material somewhere else downstream. Endlessly. These frequent hydrologic and geomorphic disturbances are part of the natural, dynamic condition of rivers and streams. The plants and animals that specialize in riparian habitats are adapted to dramatic and repeated variations in water volume, erosion and deposition, and other environmental disruptions. Compared to plants in adjacent upland habitats, riparian species can be expected to be more resilient to the increased flooding and other extreme events forecast for our region's future. Vegetation is the foundation of both aquatic and terrestrial riparian food webs, and robust hydrology supports increased plant productivity, which ripples through the rest of the ecosystem.[10] Vegetation also plays an irreplaceable role in stream habitat structure and complexity and in bank stability through the development of intricate root structures and the production of large wood,[15,18] and a robust hydrology supports that as well. Restoring stream hydrology and riparian-floodplain vegetation reinforces the natural resilience and biological diversity of these systems and maximizes their capacity to support wildlife as the climate warms.[17,19,20] Recent evidence indicates that headwater streams like Gold Creek may also respond to warming trends more slowly than previously predicted, thus providing better habitat for cold water species such as salmon and bull trout than were expected from predictions based on regional trends.[21]

Links between land and water offer wildlife the best of two worlds. Riparian areas are the transition zones between rivers and streams and the surrounding land. Wildlife and other organisms interact across the leaky divide between these systems, making each system more productive and diverse.[20] Riparian and floodplain vegetation, drawing its productivity from water resources of the stream and from the rich soils built up by seasonal flooding, provides the foundation of aquatic food webs, which in turn produce microbes, algae, insects, amphibians, and fish that are preyed on alike by aquatic and terrestrial predators of all kinds, from American dippers to kingfishers to bears and mountain lions. Mobile species such as birds, elk, and cougars may then distribute the acquired nutrients broadly across the upland landscape.[4,10,22] Restoring riparian and floodplain habitats strengthens the links between these systems, making both of them more resilient to the stresses imposed by climate change.

The characteristics of riparian areas act together to maintain moderate microclimates and thermal refugia for aquatic and terrestrial wildlife. Because riparian areas have higher water content than surrounding upland areas, they absorb heat energy and buffer temperature increases, providing cooler microclimates – thermal refugia – for plants and animals during extreme temperature events. Infusions of cold groundwater reduce average stream temperatures further while maintaining pockets of distinctly cooler water, and shade from robust riparian vegetation helps maintain cooler water temperatures. These factors support in-stream refuges for cold-water fish during extreme high temperatures, and the stream corridor microclimate provides a refuge for terrestrial species from across the landscape. Restoring riparian vegetation and protecting, replenishing, and restoring groundwater resources will make thermal refugia more resilient and available when wildlife need them most.[14,16,17,23,24,25] Gold Creek Valley's position as a broad mid-elevation valley will also help to buffer it against the more extreme temperature and habitat effects of warming, compared to similar places at lower elevations. If Gold Creek's corridor was restored to a healthy condition, its moderated microclimates would also contribute to its ability to function as a migration pathway, as discussed below.

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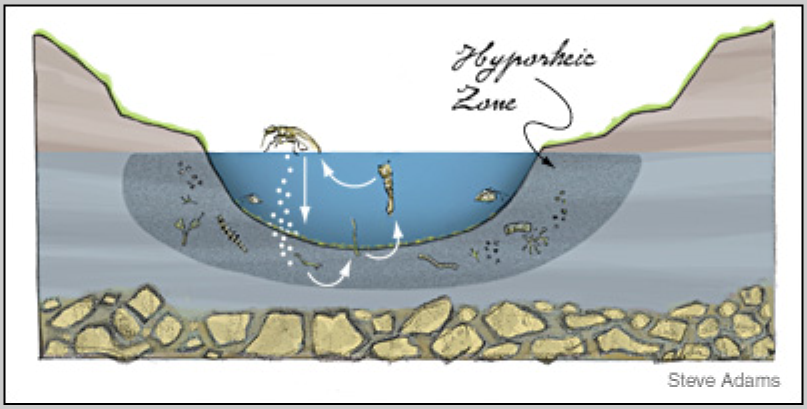
refugia*; noun, plural*

> *Areas in which a population of organisms can survive through a period of unfavorable conditions.*

Instream and floodplain complexity reduces flood impacts and dewatering. The projected effects of climate change on hydrology include changes in the seasonal patterns of precipitation and run-off, especially more precipitation falling as rain instead of snow, and will be accompanied by more frequent and extreme peak flows in rivers and streams.[23,26] Peak flows that pass downstream with few obstructions pass quickly, and most of that water is lost to the system, contributing to dewatering in places like Gold Creek. Intact or restored complex riparian and floodplain vegetation along with instream large wood can deflect, dissipate, and absorb flood energy. By slowing the velocity of peak flows, these structural elements promote water infiltration into groundwater, reduce peak flows and augment summer base flows,[18,19,27] and support greater function of the hyporheic zone (see box below),[2,23] all of which help to offset the loss of streamflow from diminishing snowpack.[17,16,23] The potential magnitude of this offset will vary between watersheds. But by reducing flood impacts and replenishing groundwater, riparian restoration at a place like Gold Creek can strengthen the resistance of both the ecosystem *and* human infrastructure to the extreme floods and hydrological alterations anticipated from climate change.



The organisms that live in the upper layers of the hyporheic zone (immediately beneath the stream) are typical of those found on the streambed itself- macroinvertebrates such as nymphs of stoneflies, mayflies, and caddisflies.

Some aquatic insects may spend most of their life cycle in the hyporheic zone, emerging only to turn to adults and reproduce. Crayfish, sculpins, darters, and other fish may sequester themselves in the gaps in the upper layer of the hyporheic zone over winter or during floods.

Different organisms live in the deeper reaches of the zone because of the smaller interstices. No plants grow here, so there are no true herbivores. But the hyporheic zone can support detritus feeders and carnivores, which feed on fine particulate organic matter and dissolved organic matter. Deeper still live mostly meiofauna, such as midge larvae. At the greatest depths, with relatively constant temperature, low oxygen, and tiny spaces between particles, are microfauna feeding on the biofilms that form on sediments.

The hyporheic zone. Minnesota Department of Natural Resources.[28]

The natural connectivity of riparian areas offers migration pathways that are becoming increasingly important to wildlife responding to warming habitats. Organisms have always moved across landscapes, constrained only by natural barriers. In the past couple of centuries human development – our cities, railroads, highways, farms, etc. – has introduced new barriers to species movements. Now global warming is disrupting habitat relationships more rapidly than ever before, and in coming decades many species and populations will have no choice but to abandon places that can no longer meet their needs and search for favorable habitats far from their traditional homes. Building stronger connections between today's habitats and potential future habitats is the most common recommendation scientists make for preserving as much wildlife as possible in the warming world.

"The emerging threat of climate change will make the need for habitat connectivity even more critical, as many species will need to adapt to a changing landscape."

Washington Wildlife Habitat Connectivity Working Group: Importance of Habitat Connectivity (2016)[29]

Figure 1. *Elk move through the Gold Creek undercrossing beneath I-90 in October 2017 (Image from Baum 2017 -- I-90 Wildlife Watch).*[30]

Riparian zones are already natural migration corridors for plants and animals.[5, 10] The productivity, water resources, and cooler microclimate of intact riparian areas and floodplains along healthy rivers and streams make them vital pathways for species that must find new habitats. An inhospitable stretch of corridor that lacks sufficient cover and food resources can inhibit wildlife movements as much as a physical barrier like a highway does, especially for smaller, less mobile species that can't pass through quickly.[31] Lower Gold Creek, with its over-widened, dewatered channel and diminished riparian vegetation, is such a place now. But restoring the hydrology and structural habitat features of these areas would increase their ability to provide the best possible migration corridors for wildlife that are or will be uprooted by climate change.[5,14,32]

The Cascades are the largest contiguous area of mostly undeveloped public land in the state. The wildlife bridges (Figure 1) at the mouth of the valley were located there because a scientific analysis recognized I-90 as a significant barrier to passage between the North and South Cascades, and Gold Creek Valley was recognized as a key link in that wildlife pathway.[33,34,35,36] This public investment, along with the restoration of degraded habitats like Gold Creek within the corridor, have to work together to help the North and South Cascades function as robustly as possible for the many species that will have to depend on them in the stressful near- and long-term futures.[17,23,25,37]

Building bridges to the future. Intact or restored riparian habitats can offer comparatively mild, resource-rich refuges and migration routes for wildlife as global warming forces them to seek temporary shelter from extreme weather locally or to search for more favorable habitats far away as their current ranges become increasingly unsuitable.[29,37,38,39] We need our riparian corridors to be in the best condition possible just to give wildlife this chance against the stresses they must face and overcome. Impaired or degraded streams and riparian areas may not provide enough of the needed resources or resilience, but restoration can increase the carrying capacity of these refuges for as many species and individuals as possible.[17,23] Gold Creek Valley holds this promise.

4. Engineered Log Jams and Gold Creek Restoration

"Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."

Society for Ecological Restoration. SER International Primer on Ecological Restoration (2004).[40]

Gold Creek Valley holds special promise. It has the potential to provide productive and resilient wildlife habitat in a warming world and is one of the few places in the Cascades that can offer wildlife the south-north migration pathway they must have if their current ranges become unfavorable. But Gold Creek, the lifeline of the valley, has been degraded in a number of ways. With this lifeline in a degraded state, the carrying capacity of the entire valley ecosystem and migration corridor is diminished. Ecological restoration is the science of how we help ecosystems to recover their ability to support as much wildlife as possible and how we accelerate the recovery of ecosystems to meet the needs of wildlife and people.

Engineered log jams are one of the important tools we have for restoring damaged river and stream ecosystems (ELJs). Across the Pacific Northwest and elsewhere, restoration engineers use ELJs to perform the roles that old-growth logs, long gone from most of our rivers and streams, once played in channel dynamics and habitat formation. ELJ design and placement is intended to nudge a river channel back towards a more natural form and behavior, promote recovery of riparian vegetation, protect human infrastructure. In other words, ELJs are meant to bridge the time it will take for today's second-growth forests to mature enough to once again produce the large wood that will perform those functions without further human intervention.[41,42,43] Since the science of ELJs was fully developed in the 1990s, "Stable large wood placements in the Pacific Northwest are now common, and numerous ELJs have successfully weathered severe floods, including events equal to or exceeding the 100-year flood" (National Large Wood Manual 2016).[43]

Through variations in design, the ELJ is a versatile tool. In the existing 60% designs for proposed instream habitat restoration in Gold Creek, Natural Systems Design (NSD) uses a system of engineered log structures to accomplish a number of project goals, in particular to direct high-energy floodwaters onto the western floodplain.[44,45,46] This would accomplish several objectives:

- It would deflect a significant component of Gold Creek's peak flow energy away from the main channel and away from STVMA's east bank of the creek, which is currently eroding rapidly and unpredictably. This direction of streamflow onto the western floodplain is designed to activate during even minor (2-year) flood events.
- On the western floodplain, water would be directed into an enhanced network of old channels, from which it could spread out and slow down as it encounters thousands of stems of trees and shrubs. This would increase the water's residence time and the surface area of water-to-soil contact, both of which promote the infiltration of surface water into groundwater[16, 27, 47] and support summer baseflows.[15]
- Several specialized ELJs would be placed to prevent water in the old floodplain channel network from taking shortcuts back to Gold Creek.

The power of a river or stream to erode its banks is a function of the volume of water and its velocity. Diverting peak flows to the western floodplain would direct a large portion of the creek's peak flow energy away from the main channel (and away from STVMA property) and would reduce the erosion potential of the entire creek below the diversion point.[45] Spreading water out and slowing it down as it moves across the western floodplain will enhance infiltration into groundwater. Water moves more slowly through the ground than in the stream channel (in summer groundwater also stays at a cooler temperature); thanks to its slow passage through the watershed, groundwater serves as a slow-release reservoir, helping to maintain summer base flows and reduce water temperatures long after snows have melted and the rains have diminished. Raising the groundwater table in the western floodplain will contribute to better productivity of riparian vegetation, enabling the habitat to support more organisms at every level of the food web.[15,27,43,44,47,48]

The hyporheic zone, an area of free interchange between a stream surface and shallow groundwater (see Section 3), may extend for yards alongside and beneath a stream channel. When a stream dewaters, the hyporheic zone can act as a refuge for stream invertebrates. These keystone components of the aquatic food web can then repopulate the active channel when surface flow.[15,49] This means that even if groundwater enhancements fail to completely rewater the creek, restoration that keeps the hyporheic zone alive improves the resilience of the stream ecosystem.

The NSD design also uses ELJs to accomplish complementary jobs, all of which will help to reduce the stream's current errosive force:[44,45,48]

- Adding roughness to the stream channel and banks to absorb and further dissipate the energy of water that remains within the main channel, further reducing bank erosion.
- Helping to carve and maintain a deeper, narrower, and more stable main channel. While the deeper channel is important in maintaining minimum flows, it is also important in enhancing the role of riparian trees and shrubs in the habitat. Riparian vegetation plays a critical role as the foundation of the aquatic food web and provides other essential functions such as stream shade and bank stability.[10, 15, 43] Right now the active channel of Gold Creek is remote from these riparian influences, and riparian vegetation along the channel is absent or underproductive because of its remoteness from growing season soil moisture (even when there *is* water in the creek) and too much scour during unmoderated peak flows.
- Protecting STVMA property from erosion along the east bank of the creek.

Overall, ELJs mimic the numerous functions of the stable old-growth logs that were fundamental to the structural and hydrological complexity of rivers and streams throughout the Cascades[15, 41, 50] and which have been missing from Gold Creek since logging of the lower valley removed all the old trees that were large enough to perform these functions. Recapturing some of these functions and habitat features is among the goals of ELJs in the Gold Creek 60% design,[40,41] including:

- Increasing the number and range of depths of instream pools. Pools are essential to stream channel habitat complexity, acting as both thermal refugia and resting/feeding habitat for aquatic organisms out of the higher velocity mainstem flow.[15,51]

- Providing complex structural habitat for fish and other aquatic organisms within and around the ELJs.
- Trapping and storing sediment and organic matter, including carbon, that contribute to physical structure and aquatic food webs.

Constructed of natural materials, ELJs will eventually disappear into the landscape, but will bridge the gap of missing large wood until the riparian forest develops to the point where large wood begins to be naturally recruited into the stream channel once again.[41,42,52]

Figure 2. Engineered log jams stand out when first installed but become integrated into the landscape as vegetation develops. This ELJ on the Cedar River in King County was installed in fall 2010 (Lorin Reinelt, King County engineer, personal communication). Above: View upstream. Below: close-up of ELJ components: anchor posts, cribbing logs, rootwad logs, rock ballast and gravel fill. Willow has fully colonized this ELJ. Photos by Jim Evans, September 4, 2017.

5. Gold Creek Valley Wetlands: How Bank Slope and Water Depth Determine Plant and Wildlife Habitat

What is a wetland?

Like riparian areas, wetlands are among the most productive ecosystems on earth. Wetlands are typical components of the stream-riparian-floodplain ecosystem and are usually hydrologically connected to a nearby stream. High-quality wetlands are capable of supporting a great diversity and abundance of native plants and wildlife. But not everything filled with water is a wetland. Here are two definitions of wetlands based on physical and biological characteristics:

*1. "**Wetlands** are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."* – U.S. EPA (2019)[53]

2. *"**Wetlands** are distinguished by the presence of water, either at the surface or within the root zone. Wetlands often have unique soil conditions that differ from adjacent uplands. Wetlands support vegetation adapted to the wet condition (hydrophytes) and conversely are characterized by an absence of flooding-intolerant vegetation."* – W.J. Mitsch and J.G. Gosselink (1997)[54]

Wetlands are not all equal in their capacities to provide habitat and produce essential resources for wildlife. Relatively shallow, gently sloping wetlands with a gradual range of water depths and a mix of vegetation types and open water provide the richest wetland habitats for the widest array of wildlife. Deep, steep-sided features like Gold Creek Pond have only a very narrow band for wetland vegetation to develop and are far less productive. The reasons for this are multiple.

Wetland environments and wetland plant ecology

Few plant species can tolerate the low-oxygen environment of saturated, or waterlogged, soils and, in progressively deeper water, the diminishing penetration of light through the water column. Because of differences among plant species in their tolerance of these environmental factors, there are distinct patterns in the occurrence of particular plant species from higher to lower elevations within a wetland basin. In a wetland, a difference of a foot or even less in elevation can mean a big difference in hydrology and in the plants that can occupy that elevation. These patterns correspond to the transition from comparatively drier soils at the top of this "tolerance gradient," as it's called, to more waterlogged soils at the bottom (Figure 3). This kind of gradient also occurs in seasonal wetlands as a result of the length of time annually that a site has waterlogged soils. In very general terms, a few tree species – but none of the evergreens -- can tolerate waterlogged soils, though not indefinitely. Willows and a number of large shrubs can tolerate waterlogged soil and even standing water for extended periods. Where the soil is too wet for any woody plants, grasses, sedges, and other herbaceous plants form wet meadows and marshes. Cattails and hardstem bulrushes ('tules') can grow in standing up to six or seven feet deep. Floating leaved plants rooted in the mucky bottom of a shallow pond, such as yellow pond lily ("spatterdock") and floating pondweed (*Potamogeton* species), are capable of growing in still deeper water, out to about ten feet or so (Figure 4); anything growing beyond that depth is exceptional.[55,56,57,58] Deeper water habitats than this are not without some value, but by far the greatest production, biological activity, and plant and animal diversity is associated with shallow water habitats.

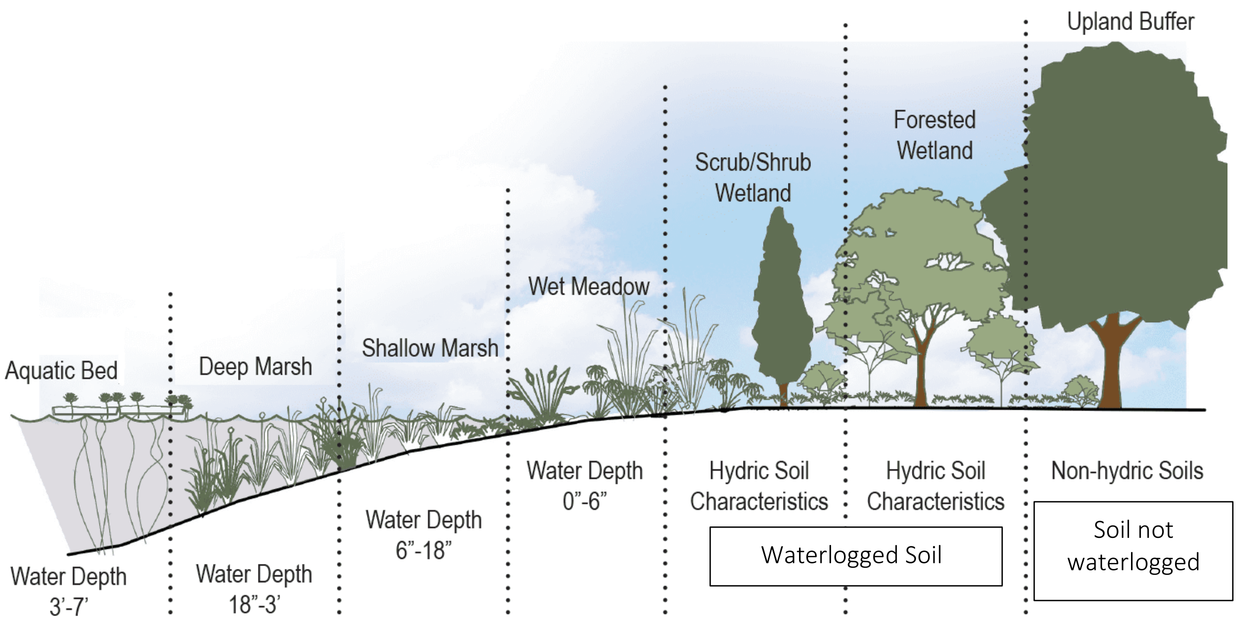


Figure 3. Conceptual diagram of wetland plant communities in relation to increasing water depth. Wetland plants are limited by dry soils at the upper elevations of a wetland complex and by tolerance for waterlogged soils and progressively darker conditions (under water) at the lower elevations. Little to no wetland vegetation grows below a depth of 10 feet. Open water habitats beyond that depth have far less habitat value.[59, 60, 61, 62, 63] *Figure from Great Rivers Greenway (2021).*[64]

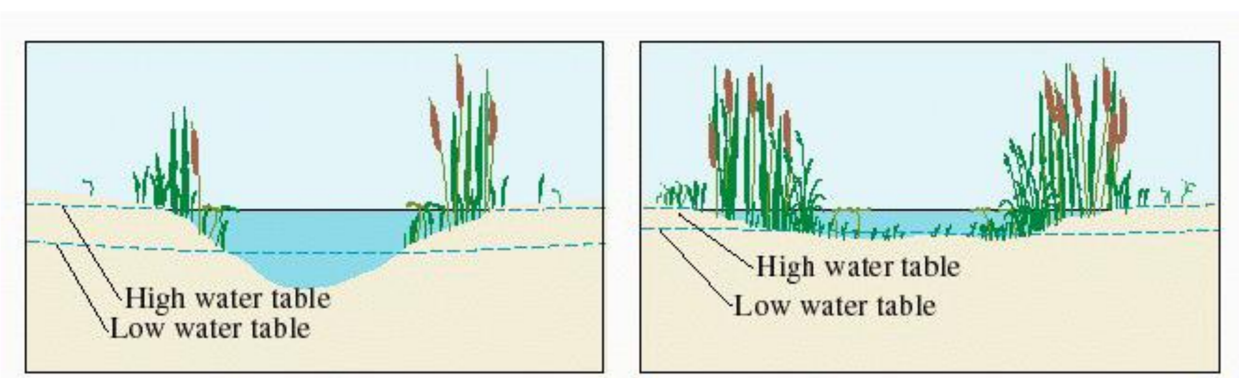


Figure 4. Conceptual diagram of the relationship of basin slope and depth to wetland vegetation tolerances. The range of vegetation depicted in this figure is comparable to the "wet meadow" to "aquatic bed" plant communities shown in Figure 3. Figure from Kentula (2002).[65]

The presence of water (including soil water) and thick vegetation in wetlands produce a very localized microclimate that is generally more humid and has milder temperatures than the surrounding non-wetlands. This favorable microclimate plus the nutrient-rich soils of wetlands lead to much higher productivity compared to surrounding uplands. This productivity cycles throughout the food web to insects, amphibians, birds, and mammals. And, through mobile species such as birds, elk, bear, and cougars, it can spread far beyond the wetland into the wider ecosystem.[66]

Along with this productivity, well-developed wetland plant communities also provide critical habitat structure for many species. Insects and other smaller aquatic creatures live out their lives attached to the stems and undersides of the leaves of wetland plants. Amphibians attach their egg masses to the stems of plants standing in the water. Later, the emerged tadpoles feed among the stems and hide from predators under the broad leaves of pond lilies and other floating-leaved plants. Beavers and waterfowl feed on and among the stems, and large grazers like deer and elk feed directly on the lush produce, sometimes standing in the shallow water to do so.[59,66] While natural valley wetland basins have shallow slopes, steep slopes limit the types and extent of this kind of vegetation and habitat.[65] In other words, **steeper-banked ponds support less wetland plant habitat**. And that means they support less life of almost every other kind.

How basin topography shapes wetland habitats

Any of us who have hiked in the Cascades have visited alpine lakes such as Alaska Lake, Lake Lillian, or Joe Lake, deep bowls of clear water carved by glaciers out of the underlying bedrock. While those kinds of waterbodies are common higher in the Cascades, they are not characteristic of broad floodplain valleys like lower Gold Creek Valley.

Floodplains like Gold Creek's are built up over hundreds or thousands of years as flood after flood spreads out and deposits relatively even layers of sediments across the valley floor. The Valley receives additional moisture from the surrounding slopes and springs, and shallow wetlands can develop in the gentle topography of the valley floor. A perfect example of this kind of natural floodplain wetland is the wetland complex on the western floodplain of Gold Creek, roughly across the creek from Heli's Pond (Figures 5 and 6).

The area that the Washington Department of Highways (WDH, a precursor to the Washington State Department of Transportation) developed as a gravel mine and which eventually became Gold Creek Pond was once an area something like this. Numerous memos, reports, and other WDH historical documents concerning the area refer to the original condition of the site as a spring-fed swamp.[67,68] As a technical term, "swamp" refers to a forested or shrub-dominated wetland (as opposed to a marsh, where trees and shrubs are typically absent and herbaceous plants predominate). The documents describe conditions characteristic of forested wetlands, with examples such as the following.[68]

- 1966: "This is a swampy area with standing and fallen trees throughout. Much organic matter. Many buried logs and like debris." When test pits were excavated WDH field staff found buried logs to a depth of 11 feet.
- 1967: A memo describes the area as "quite swampy" with numerous downed trees and snags.

- 1975: "Required stripping of 3-5' of black muck." "5' of overburden of black soil and logs must be stripped from surface of remainder of pit." ("Muck" is both a technical term and a descriptive term referring to fine black soil, rich in undecomposed organic material, formed in wetlands as a result of extremely low rates of decomposition due to waterlogged, or oxygen-poor, soils.[69])

Other documents refer to the elevation of the wetland surface above Gold Creek and to the high-water table in the wetland:

- 1967: "The area, most of which is quite swampy, is situated some 5 to 8 ft. above the existing stream bed of Gold Creek."
- 1968: "During our pit investigations on S-156 extension the water table was encountered generally at depths of three to five feet in the northerly segment of the pit."

These memos indicate that **the water table in at least part of the swamp was at or higher than the elevation of the creek**. The wetland also had a surface-water connection to Gold Creek, according to a 1967 letter which expressed concerns of officials at the Washington Department of Game (a precursor to today's Washington Department of Fish and Wildlife) about "fish now spawning in the swamp."[68]

The topography of Gold Creek Pond is unlike that of the original swamp that occupied the site, or of any natural valley bottom wetland, and doesn't allow for the habitat complexity that makes such a wetland a vibrant resource for wildlife. When the freeway builders were finished mining gravel at Gold Creek Pond, the final reclamation plan for the site specified a 3:1 slope for the banks of the pond; that is, a one-foot drop in elevation for every three horizontal feet.[68] A 3:1 slope is a steep one. Because of the limited depth tolerances of wetland vegetation (as noted above in the discussion about wetlands), slopes this steep at Gold Creek Pond (Figures 7 and 8) offer only a narrow fringe of potential habitat for wetland plants to occupy before depths become too great for them. Therefore, all the organisms that occupy those kinds of habitats are limited as well.[60] Diverse communities of algae and insects occupy the stems and leaves of wetland vegetation, greatly multiplying the surface area of biological activity and providing a foundation for higher levels of the food web. Pacific Northwest frogs and salamanders lay their eggs on wetland vegetation within a specific, limited range of water depth, only between about 4" and 40" deep. Biologists recommend slopes as shallow as 15:1 with a relatively small proportion of open water for constructed or restored wetland habitats.[59,60,61,62,63,70]

Figure 5. *Natural wetland complex in Gold Creek Valley, located on the floodplain west of Gold Creek, and a little up-valley from Heli's Pond. This large, shallow wetland includes a range of plant and wildlife habitats based on water-table depth, from willow swamp and sedge marsh through floating-leaved wetland vegetation and shallow open water. Where conifers are growing indicates the upland limit of the wetland. Photo from Kittitas Conservation Trust website.*

Figure 6. *Ground level view of the wetlands pictured in Figure 7, July 2018. The floating-leaved yellow pond lily in the foreground indicates a water depth of 6-7 feet or less. In the middle distance, sedges, buckbean, and other herbaceous plants indicate of shallower water. Behind the herbaceous vegetation lies willow swamp. Vegetation is the basis of the food web in wetlands and provides structural surfaces – stems and leaves – that are colonized by a zooscape of tiny organisms and provide breeding and feeding habitat for frogs and salamanders. This is a gem of a wetland! Photo by Jim Evans.*

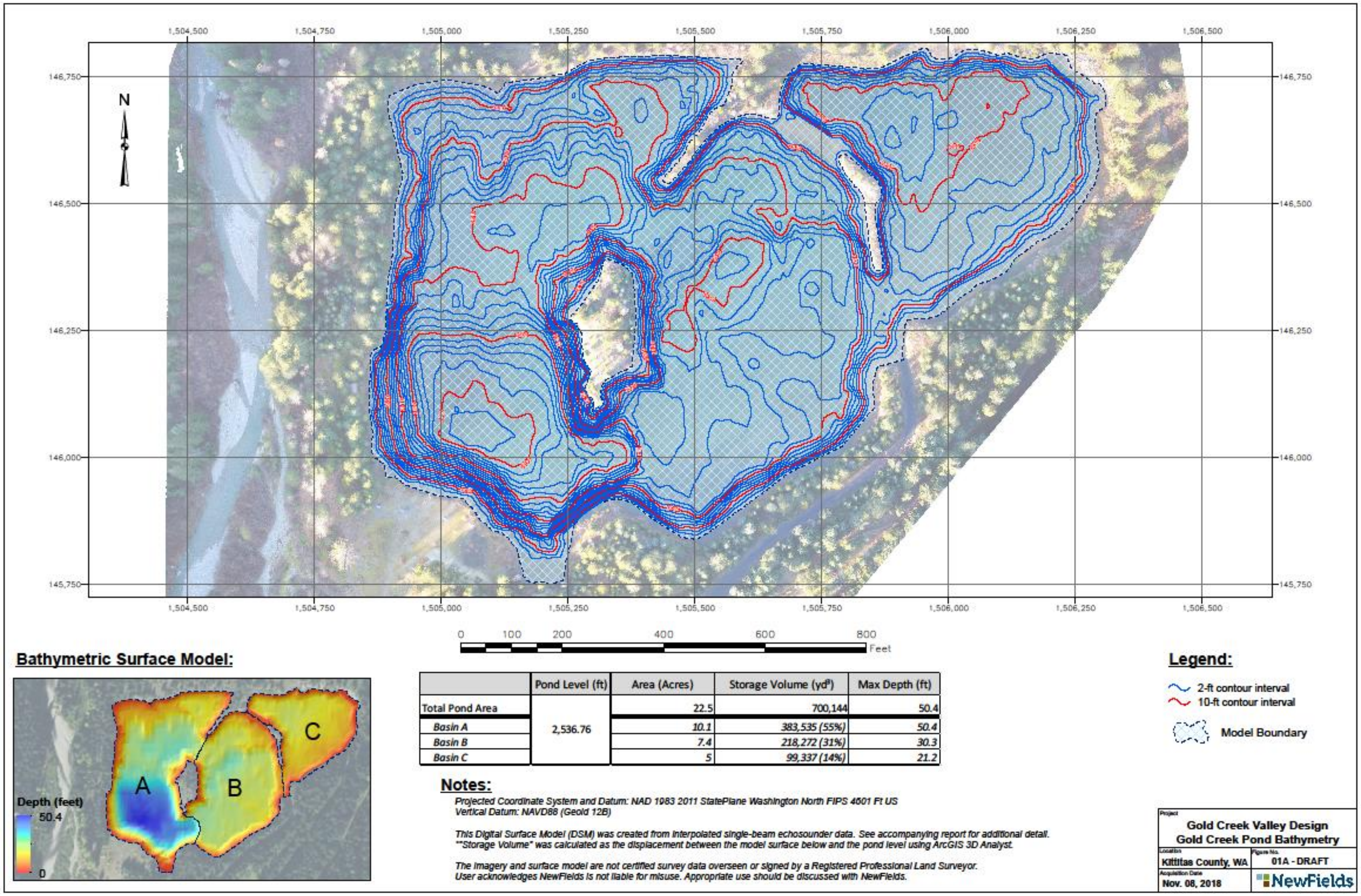


Figure 7. *Below-surface contour map ("bathymetry") of Gold Creek Pond, 2013. From a U.S. Forest Service study supplied to Jim Evans by the Kittitas Conservation Trust in June 2019 and displayed on a poster at the STVMA membership meeting and potluck later that month. The maximum depth of the pond is just over 50 feet in Basin A. Note the steep slopes indicated by the tightly packed contour lines that occupy nearly all of the shorelines, including islands and peninsulas.*

Figure 8. *Aerial view of Gold Creek Pond. Compare to Figures 5 and 6. The steep 3:1 slopes and deep water of the former gravel mine site restrict the development of wetland vegetation and all of the biological diversity it supports to the narrowest of fringes. Some remnants of the former wetlands at the site persist in groundwater seeps coming off the base of Rampart Ridge, seen here in the upper left corner of the image (that is, the northeast corner of the site, where the trail crosses the boardwalk) where wetland vegetation occurs perched on the banks above the current pond elevation and running down to the pond itself. Groundwater also shows up in many seeps along the north shore of the pond. Photo from Kittitas Conservation Trust website (2021).*

6. Effects of Trapping, Logging, and Mining in Gold Creek Valley

"The effects of historical human alterations have, in some cases, been forgotten by society when the activity that triggered the alteration is no longer occurring."
– Ellen Wohl. Forgotten legacies: Understanding human influences on rivers (2019).

Gold Creek is like many other rivers and streams in the Western U.S. in that human activities have dramatically altered keystone features of the stream-riparian ecosystem, diminishing key functions of the ecosystem along with the ecosystem's wildlife carrying capacity.[71,72,73] In Gold Creek Valley, the extraction of natural resources – fur, timber, and gravel – as practiced in the 19th and 20th centuries profoundly altered the hydrology and geomorphology of Gold Creek and resulted in the habitat conditions we see in the Valley today. The following section discusses the historical records of these practices, where available, and their associated impacts.

Trapping

I don't know of any documentation regarding American beaver populations or their harvest in Gold Creek or the upper Yakima Basin, so it's impossible to draw firm conclusions about historical beaver populations or the extent of their influence on Gold Creek. It is very reasonable to assume, however, that fur trapping was probably the first intensive harvest of a natural resource that affected the functioning of Gold Creek, even if we are uncertain of the magnitude of this effect. Beaver were almost certainly historically present in a valley that would have looked very different from the one we see today, and they most likely occupied most or all of the available appropriate habitat in the lower valley, because that was the case almost everywhere across forested North America prior to intensive trapping in the 19th century. Scientists estimate that, before the arrival of Euro-Americans, 50 to 100 million beavers built and maintained dams on nearly every small and most mid-sized streams in North America. In areas where beavers are abundant and undisturbed today, dam densities as high as more than 100 per stream mile have been observed, although average numbers across the range are between two and 10.[74]

This is significant because beavers exert a profound influence on stream channel morphology, groundwater hydrology, and floodplain habitat structure. By building dams and impounding water, the beaver acts as a keystone regulator of stream velocity and bank stability, and beaver ponds vastly increase hydrologic connectivity between the stream and its floodplain, thereby increasing surface water retention and groundwater infiltration and storage, critical processes that support natural river systems.[15] In many systems the contribution made to summer baseflows by the groundwater recharge and storage associated with abundant beaver complexes makes the difference between perennial flow and intermittent dewatering.[74,75,76]

> *"Based on our observations of stream systems in the western United States, it is likely that many intermittent streams could have perennial flow restored if beaver colonize them."*
> **Michael Pollock**, Ph.D., NOAA Northwest Fisheries Science Center, Seattle: Hydrologic and geomorphic effects of beaver dams and their influence on fishes (2003).[67]

Despite their huge population size at contact, unregulated trapping drove beavers to near extinction across almost their entire North American range by 1900. In the Pacific Northwest, most of the damage was done by 1850. Harvest intensity was so great that it is extremely doubtful that many beavers in the Snoqualmie Pass area escaped the trap.[74]

In watersheds where beavers were trapped out, the deterioration of their unmaintained dams was accompanied by the loss of their positive effects on hydrology and geomorphology. Freed of obstacles, watercourses ran more swiftly and with more erosive energy, widening channels and reducing habitat complexity. Water passed through the system much more quickly, reducing surface water retention and infiltration, reducing groundwater storage, even draining floodplain wetlands, and reducing the contributions all of these factors made to maintaining summer baseflows.[48,74]

Although beaver populations have recovered somewhat, numbers today stand at only 10 to 20 million animals. Thousands of rivermiles of suitable habitat remain unoccupied, and many watersheds have not recovered from the geomorphic and hydrologic consequences of the extirpation of their beavers.[74, 76,77] In efforts to reemploy the beaver's talents for enhancing watershed hydrology and habitat complexity and to enhance groundwater storage as compensation for hydrological losses anticipated as a result of climate change, restoration professionals are increasingly trying to accommodate, encourage, and/or reintroduce animals in recovery projects or, where reintroduction is currently not feasible, to mimic beaver dams using specially engineered wood structures.[51,78,79]

Beaver extirpation was relatively complete in the Northwest before 1850[73], a half-century before our earliest photographs of Gold Creek. We will never know for certain the effects a historic beaver presence or their removal had on Gold Creek, but it is reasonable to assume that they bore a close resemblance to the effects described in place after place across the rest of North America.

Logging

The Lake Keechelus Basin was clearcut in the 1910s prior to filling the pool behind the newly constructed dam,[80] and it's likely that at least some logging had taken place in lower Gold Creek Valley at or before that time. Timber harvests began farther up the Valley by the mid- to late-1940s or early 1950s. By the mid-1950s, there were extensive clearcuts upstream from Sunset Highway (the precursor to I-90), both along the valley bottom and on the lower slopes to the west (Figure 9). Forest practices rules at the time were not what they are today, and though a thin band of trees appears to have been left along the creek in some places (we don't know whether or not the harvest was complete or still going on when these photos were taken), in other places it appears trees were removed right to the creek's edge. At the large wetlands in the western floodplain of Gold Creek cut stumps are found right up to the water's edge (personal observation), and there's every reason to presume that this was the practice along the creek as well.

Surveys of stumps and logs around the Valley indicate that Douglas-fir and western redcedar were significant components of the original forest of Gold Creek Valley, along with the western hemlock and silver fir that predominate today,[81] and that the forest contained numerous individuals with trunk diameters four to five feet across and larger (JE, unpublished data). The presence of numerous large trees, including Douglas-fir, is corroborated by large individuals that can still be seen along and just off the Gold Creek Trail past the up-valley extent of logging, in the Lake Keechelus stump forest, and by patches of original forest that survive elsewhere in the Snoqualmie Pass area.

The significance of these large coniferous trees is that large trees eventually produce large logs. Old-growth logs are irreplaceable features in Pacific Northwest streams because, unlike smaller logs, they can be relatively immobile in a dynamic stream environment. Acting as individual logs or as key pieces around which log jams form, large wood performs a major role in slowing water velocity and absorbing stream energy, promoting both channel stability and habitat complexity. They may also provide anchor points for beaver dams in energetic streams, facilitating the geomorphic and hydrologic functions of those structures. All logs of sufficient size may function in these ways, but differences in decay rates in water mean that some species' logs last longer than others. The slow decay rate of Douglas-fir logs when waterlogged in streams and the slow decay rate of western redcedar under almost any conditions mean that large logs of these species can function as key pieces for many, many years.[16,18,41,42,45,47]

Large wood and log jams were abundant in forest-lined rivers throughout the Pacific Northwest. Where historical records are available (mostly from the Puget Lowland) the densities of old-growth logs in rivers and streams were astonishingly high, to a point that those of us alive today have seen nothing like it.[82,83]

Existing large wood within Gold Creek's channel would not have disappeared instantly after logging (although high-value cedar may have been "salvaged" from the stream channel). However, deprived of its sources of replenishment, Gold Creek gradually lost the channel-regulating and habitat-forming functions of large wood. Without a self-replenishing supply of large wood, the stream began to run faster, accumulating greater energy to erode away at banks and to cut across meanders, leading to a wider, straighter channel. A straighter channel would have further contributed to increasing steam velocity and energy in a feedback loop that continues today.[84] Peak flows rush down the channel with little to slow them down and without the residence time necessary to recharge groundwater.

Studies at a research site in British Columbia found that clearcutting to the streambanks resulted in a 50% decrease in large wood in the stream in just a few years. The practice also led to accelerated bank erosion and sediment mobilization and widening of the stream channel. Accelerated erosion and widening continued for over a decade. Reduced streambed stability resulted in channel simplification, including the filling in of pools, seasonal dewatering in some areas, and channel avulsion in several areas. Riparian vegetation had not recovered in 12 years, and all of these impacts had significant effects on aquatic organisms, from insects to fish.[85]

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noun: avulsion

A sudden cutting off of land by flood, currents, or a change in the course of a river.

Forests usually regrow after harvest, but the consequences of overharvesting persist for decades and decades. The replacement time for the old-growth-size logs that used to populate the floodplain of Gold Creek is at minimum 100 to 150 years post-harvest, and the process can't be speeded up. The keystone roles that large wood plays in a stream ecosystem were poorly understood and consequently undervalued at the time the lower Gold Creek Valley was logged. But given what we know today, it's no surprise that the clearing of the old-growth forest pushed Gold Creek beyond a point where the ecosystem could repair itself and set in motion a cascade of negative effects on habitat complexity, channel stability, erosion, and hydrology that we still see today. Systems affected like this are not expected to regain their lost functions and stability within a biologically meaningful time period except with human assistance.[41]

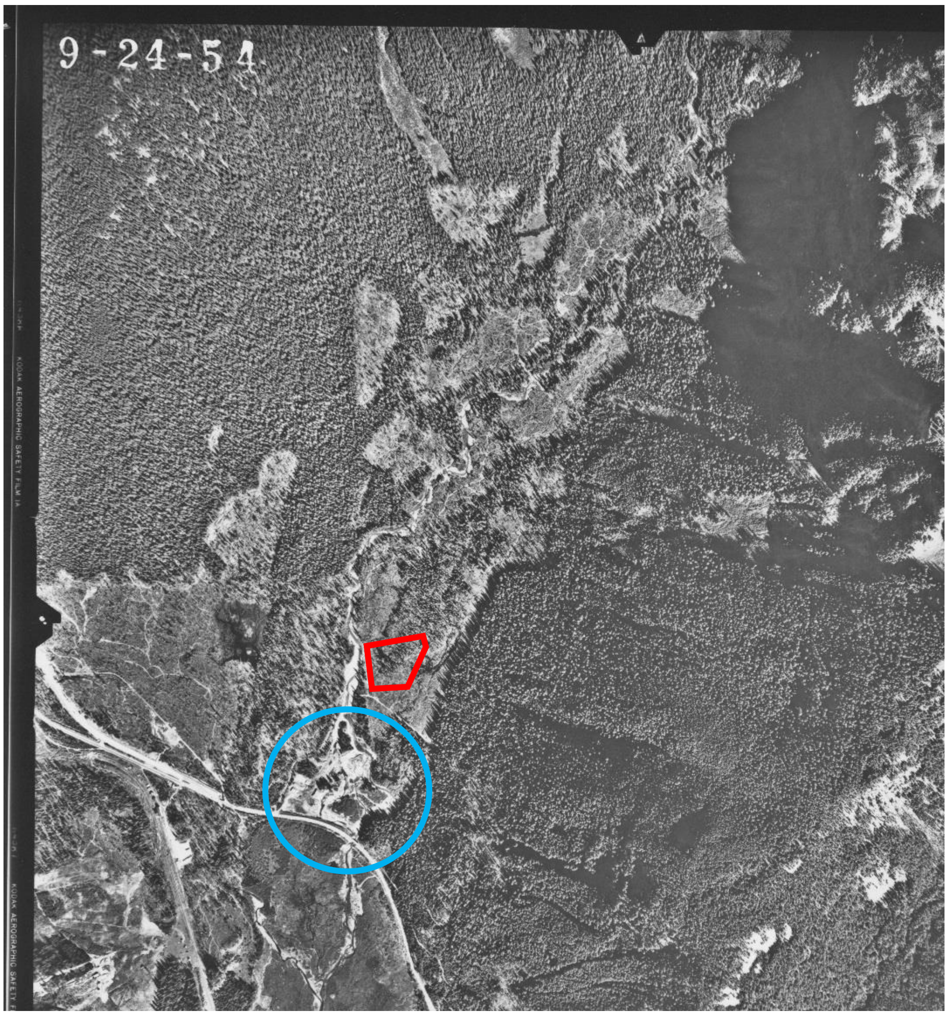

Figure 9. *Lower Gold Creek Valley, September 1954. Extensive clearcuts are evident along the valley bottom. Trees appear to have been left along some reaches of the creek but harvested along others (we don't know for certain whether or not the harvest was complete or still going on when these photos were taken). An intensive gravel mining operation (PS-5134) has begun in the stream channel next to the highway in the lower left-hand corner of the image (blue circle). The red polygon indicates the approximate position of Gold Creek Pond today. A widened section of Sunset Highway can be seen approaching from the west, but construction has not yet reached the Gold Creek crossing. Central Washington University photo (2021).[86]*

Mining and roadbuilding

Mining began in Gold Creek Valley at least as early as the 1880s. A U.S. Forest Service report states that a "Flanagan Mining Company" built a tramway trestle down Gold Creek to where the tramway met the wagon road that existed at that time.[67] The exact location of the trestle could not be determined but was likely at or near today's Gold Creek Pond parking lot, a place designated as "old state road" on a 1958 WSDOT sketch map (Appendix D). The author(s) of the Forest Service report found no documentation describing how far up the creek the trestle went, where the actual mining operation was, or what impacts its construction and operation had, but speculate that large trees were likely cleared from the Gold Creek floodplain to clear the route and perhaps for construction materials.

Small-scale mining for silver and copper began near the head of Gold Creek Valley at least by the 1890s,[87] but it was an appetite for gravel for road building that would result in significant impacts to Gold Creek and its floodplain.

As the lowest elevation crossing of the Cascades, Snoqualmie Pass has always been a focal area for east-west travel. A substantial bridge was built across Gold Creek at least as early as 1914 (Figure 10). This would have entailed at least some excavation for footings and for gravel used for the approaches. The bridge and its footings would have restricted Gold Creek from access to its floodplain in that vicinity, while increasing stream volume, velocity, and bedload carrying capacity through the relatively narrow span.[88,89] Given the practices of the day, ongoing improvements and maintenance of the road – first dubbed "Sunset Highway" in 1915[90] – in the Gold Creek area would likely have made use of gravel from the nearby Gold Creek channel.

Figure 10: 1914. *Gold Creek Bridge, Sunset Highway, Snoqualmie Pass, October 19, 1914 Photo from Washington State Archives (WSDOT AR20130226-01 985)* in *Ott (2013).[90] Note mature forest in the background of the image.*

An increase in automobile ownership and highway use following World War II was accompanied by more upgrades of Sunset Highway. In the early 1950s the Washington Department of Highways (WDH), predecessor to today's Washington State Department of Transportation (WSDOT), began a major project to widen the highway to four lanes. This project included the establishment of a large-scale gravel mining operation, Pit Site PS-S-5134, directly in the active stream channel and floodplain of lower Gold Creek (Figures 9 and 11).

Instream gravel mining is a profound disruption of a stream-riparian ecosystem, and ecological consequences of such operations can ripple far beyond the extraction site itself.[31,49] Likely impacts to the aquatic and riparian ecosystem include:

- Direct disruption of instream habitat and removal of riparian vegetation.

- Accelerated bank erosion, channel incision (downcutting), and channel widening.
- Disruption of the hyporheic zone and lowering of the groundwater table. Groundwater levels may be affected far upstream from the extraction site.
- Where the water table drops below the rooting zone of moisture-requiring riparian vegetation, depletion or elimination of vegetation type, resulting in the system losing productivity at all levels of the food web.
- Mobilization of sediments and smaller gravels, resulting in excessive downstream deposition of these finer materials and a coarsening of remaining bed materials at the site itself. This alters habitat suitability for fish and many other aquatic organisms, and further affects groundwater retention and exchange characteristics.

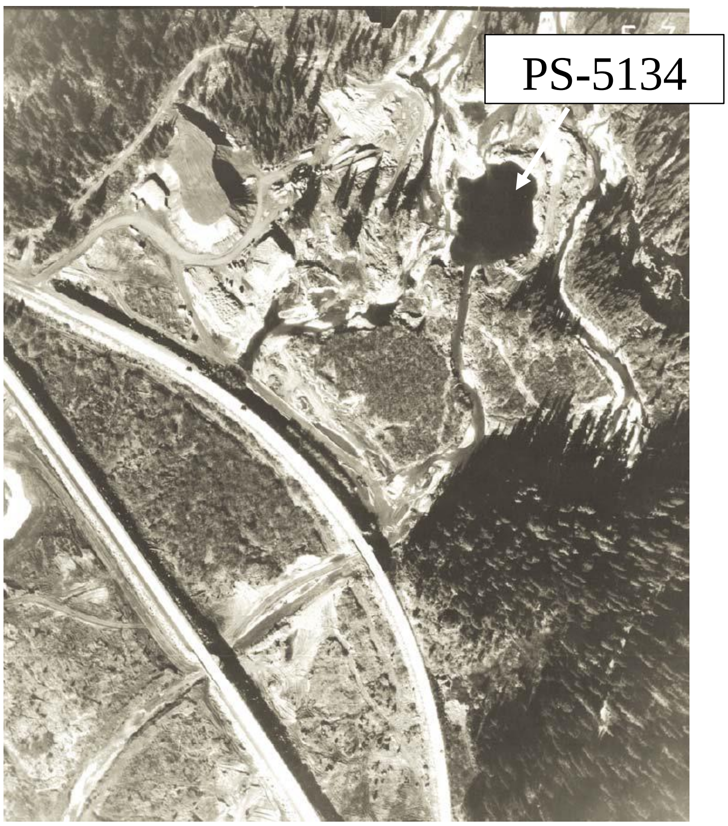

Figure 11: 1957*. Large-scale instream gravel mining operation (Pit Site PS-5134) in lower Gold Creek just upstream from Sunset Highway. The chaos of channels, pits, and workings makes it impossible to discern just which channel is the main channel. Instream mining can disrupt groundwater elevations potentially far upstream, as well as having significant consequences for other key ecosystem functions.*[31,49] *Washington Department of Transportation image.*

While instream mining was still under way at PS-S-5134, WDH began searching for sources of gravel for additional highway projects in the Snoqualmie Pass area. Interest soon became focused on Gold Creek Valley upstream from the PS-S-5134 operation.

Except where noted, information in the following section comes from documents and imagery provided by WSDOT following a Public Documents Request made in February 2021.[68] For a chronology of field investigations, permitting, and mine development at the present-day site of Gold Creek Pond with more detail compiled from these documents, see **Appendix D. Detailed Timeline …. of Pit Site PS-S-156 in Gold Creek Valley, 1958-1986.** In summary:

- The eventual site of Gold Creek Pond, in Section 14, was not the only place in Gold Creek Valley of interest to WDH's materials specialists. Beginning in 1958, sampling and testing of materials for project suitability was conducted at sites in Section 11, owned by the Northern Pacific Railroad, and in Section 14, in the Wenatchee National Forest. WDH named the sites PS-S-156 Extension A (Section 11) and Extensions B and C (Section 14). Subsequent sampling was conducted on both properties up through 1966.
- In Section 11 (where the Ski Tur Valley community now sits), interest was focused in the channel of Gold Creek and its adjacent floodplain in the southwest quarter of the section. Test pits were dug directly in the channel of Gold Creek in 1958 and in 1966. In 1966 eight test pits were dug in the channel. Pits were dug with a backhoe and were fairly large: 6.5 to 12.5 feet deep and 15 feet x 15 feet wide at the surface. WDH analysis of samples indicated that the material was suitable for the anticipated highway projects. An operation 200 feet by 3300 feet "lying athwart Gold Creek" was expected to yield 238,000 cubic yards of raw material.
- During this same period WDH staff were investigating gravel resources beneath a forested wetland on Forest Service land in Section 14. This site, in the eastern floodplain of the Valley, was designated PS-S-156 Extension B. Test pits dug in this area revealed that it too harbored suitable material, under several feet of wetland muck, trees, and logs.
- Because Burlington Northern and Robert Hansen, the original Section 11 lease holder, were interested in developing Section 11 for recreational cabins, WDH requested a permit to develop a gravel mine on the site of the Section 14 swamp. This was four years before passage of the Clean Water Act, and wetland protections were not what they are today. After a period of negotiations, the Wenatchee National Forest issued WDH a Special Use Permit to develop a gravel mine, designated simply PS-S-156, in the northwest corner of Section 14, where Gold Creek Pond is now. The initial Special Use Permit was granted on May 7, 1968, and states that "Construction or occupancy and use under this permit shall begin within __1__ months." *In other words, use of the site was expected to begin in summer 1968.*
- Work on the Snoqualmie Pass to Hyak lane expansion on I-90 began in the summer of 1968.[91] It seems likely that material for the project came from the nearby PS-S-156 mine in Gold Creek Valley.
- While there's no conclusive information that excavation began in 1968, surface photos show that excavation of PS-S-156 was well-advanced by summer 1969 (Figure 12). The fully developed site occupied nearly the entire eastern floodplain of Gold Creek at one of the broadest points in the valley (Figures 13 and 14). WDH site development included the construction of a hard earth and riprap levee along the west side and northwest corner of the site to prevent avulsion of the creek into the pit.
- Gravel mining at PS-S-156 ended in October 1983, 16 years after the initial Special Use Permit was issued (Figure 15). **The forested wetland that once occupied the site had been transformed into a steep-sided, 50-acre pond, with another 30 acres or more of surrounding land heavily disturbed by stockpiles, haul roads, and armoring of the Gold Creek streambank along the western boundary of the site.**
- Reclamation work at PS-S-156, what we know today as Gold Creek Pond, was completed in October 1986.

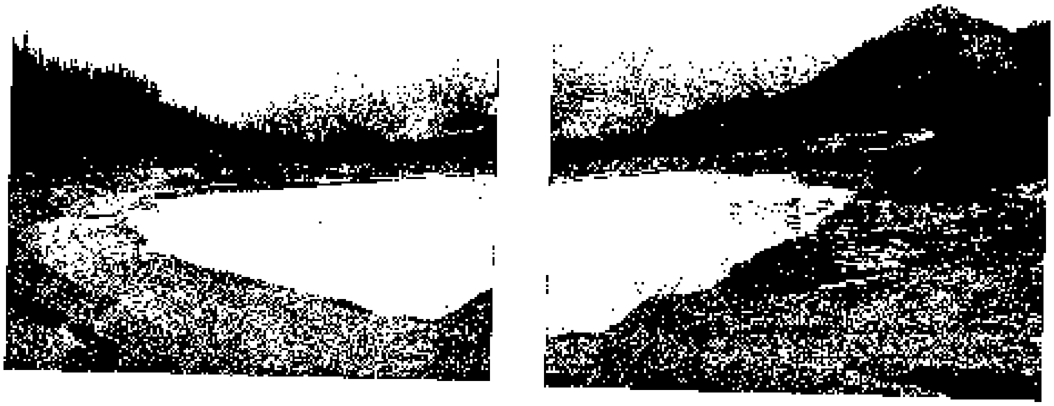

***Figure 12**. Pit Site PS-S-156, 1969 (WSDOT). The poor legibility of these images is because WSDOT provided only PDFs of photocopies of the original photographs. Nevertheless, a large ponded excavated area, and recognizable topography surrounding the pit/pond site are plain. Inscriptions accompanying the images are as follows (verbatim): Left: "Pit S-156 Ext. looking south from near northeast corner. 1969." Right: "Pit Site S-156 Ext. looking south from near northwest corner, showing dragline operation. 1969." The dragline tower is barely visible in silhouette in this very poor reproduction.*

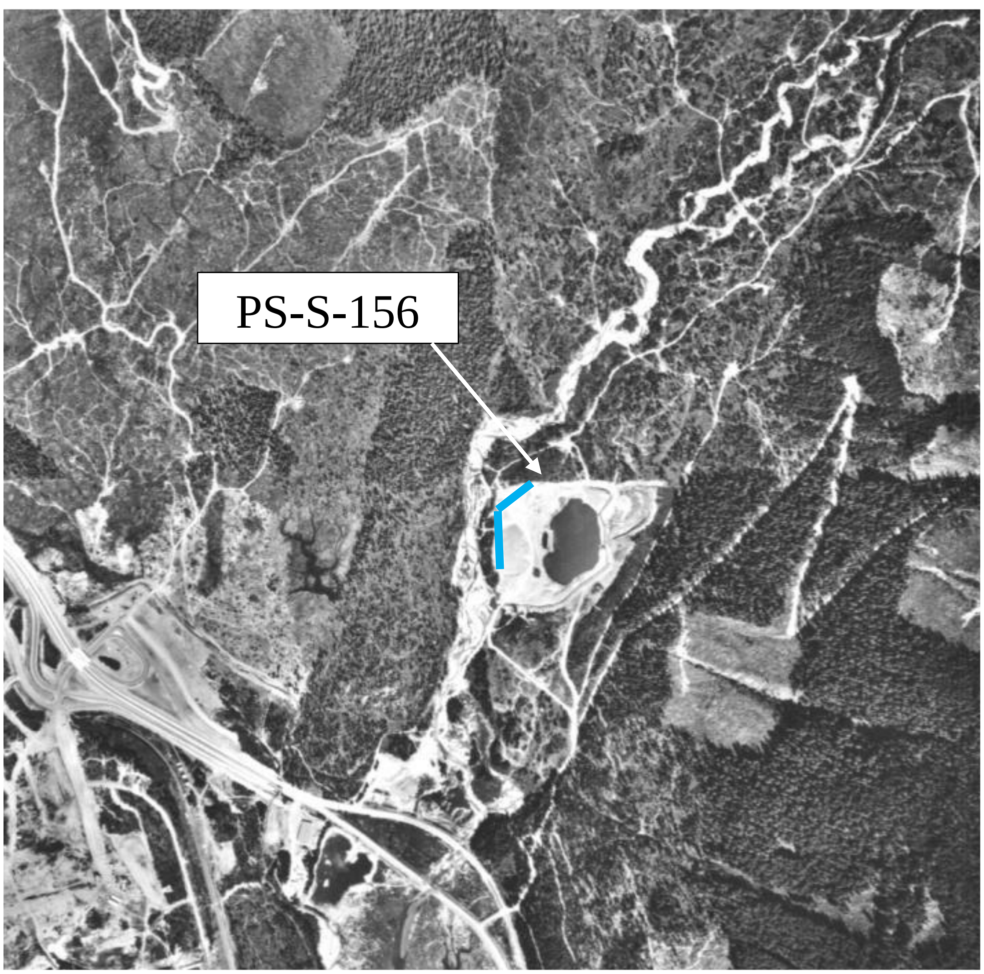

***Figure 13: 1970**. In this image the widening of I-90 is proceeding from the west but has not yet reached the crossing over Gold Creek. What we now know as the Frontage Road is still part of the highway. Pit Site PS-S-156 has already been extensively excavated and the central part of the pit has filled with water. The blue line indicates the levee built along the west side and northwest corner of the site to insure against avulsion of Gold Creek into the pit site.*

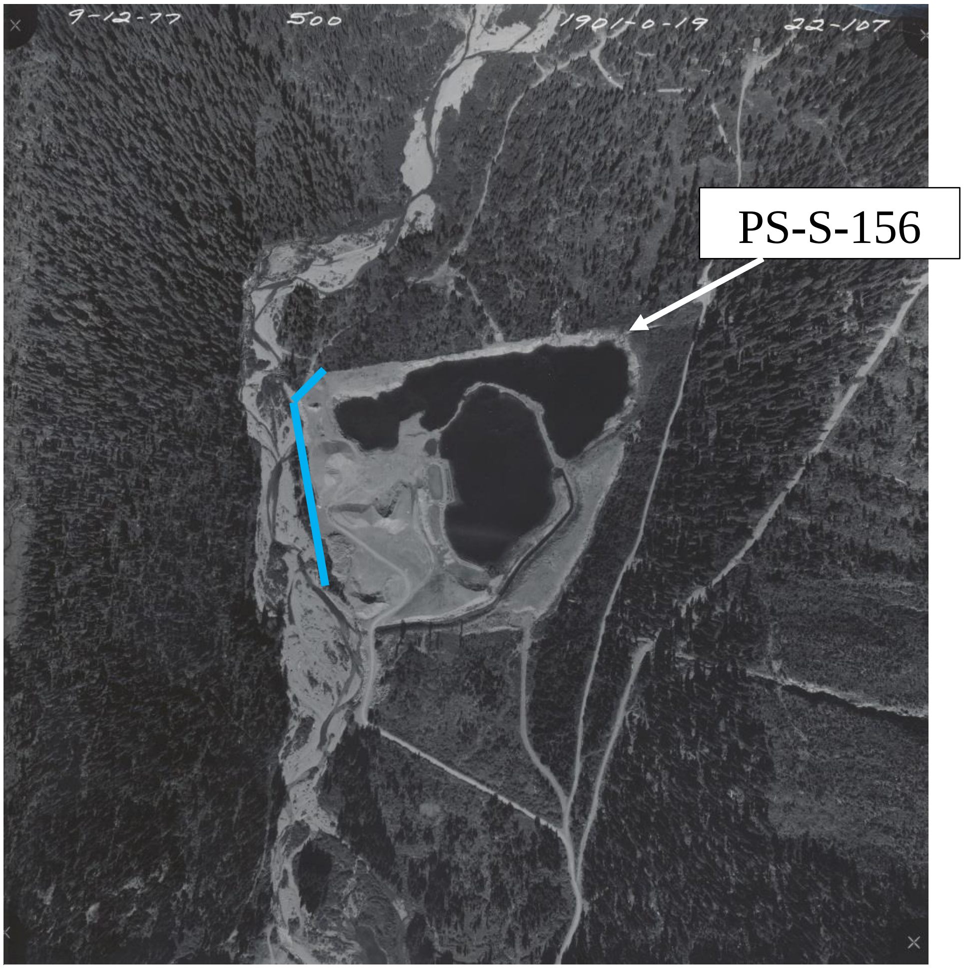

***Figure 14: September 12, 1977**. PS-S-156 was active for 15 years and through multiple highway projects. Here, somewhat more than halfway into that period, the site is not yet fully excavated. A large stockpile area is visible in the southwest corner of the pit area. The blue line indicates the riprap levee, as in the previous figure (aerial image furnished by WSDOT).*

A development on the scale of the PS-S-156 gravel mine was certain to have significant and wide-ranging effects on the ecology of the lower Gold Creek Valley. This development separated Gold Creek from nearly its entire floodplain at one of the broadest points in the Valley, impairing vital processes of stream channel dynamics, instream habitat formation, riparian and floodplain productivity, and hydrological exchange.[3,92,93] Additional impacts include the following:

- The excavation converted approximately 80 acres of complex forested wetland and buffer habitat into a deep, steep-sided, open-water pool, resulting in an appreciable diminishment of the web of wildlife the previous habitat type supported, including fish spawning habitat (Section 5).[68]
- Water temperature increased in Gold Creek. Forest Service workers observed cold water (40-44^o F) entering Gold Creek Pond from springs on the east and north shores but measured temperatures in the pond itself and its outlet channel of 65^o F and above, temperatures that exceeded water quality standards and were unfavorable for salmon and bull trout and the aquatic insects that are important food sources for juvenile fish.[94,95]
- The construction of earth and riprap levees along the west side of the site unnaturally straightened and confined Gold Creek to a limited corridor pressed against its narrow

floodplain in that part of the valley. Straightening and confining rivers and streams results in faster flow, increased erosion and bedload transport capacity, instream and side-habitat simplification, and a reduction in groundwater recharge, among other biological and geomorphic effects.[3,93,96]

"An aggraded river is difficult to detect and repair because it changes so slowly that we forget what the river looked like in its pristine state. The events that led up to the present problem may have originated back in time beyond the memory of present-day residents. 'Well, the river has always looked that way.'"

Jim Lichatowich, fisheries biologist. River of Stone (1991).[97]

No one alive today has seen Gold Creek in its pristine, fully functional condition. Most likely, trapping and certainly logging and gravel mining at the scales that occurred in Gold Creek Valley profoundly changed the hydrology, geomorphology, and wildlife habitat quality of the Valley ecosystem. Beaver will use existing instream structure to anchor their dams, and it is highly plausible that an ever-replenishing supply of instream old-growth logs combined with in-channel and off-channel beaver dams in the numbers that have been observed in places where over-trapping did not occur once had stabilizing effects on flow rates, channel structure, and groundwater recharge greater than what either factor could contribute individually, resulting in stream conditions far different from what we see today. Gold Creek's hydrology was already severely impacted by the depletion of these resources even before large-scale gravel mining operations began in the 1950s and continued into the early 1980s. But these later actions aggravated existing ecological problems and created new ones. Euro-American users of the Valley in the 19th and 20th centuries did not have the benefit of knowledge we have today, and the ecological consequences of their practices were almost entirely unintended and unforeseen.

Ecosystems can recover from moderate disturbances, but **overharvesting of keystone ecosystem components or extreme disruptions to sensitive resources can push an ecosystem beyond its capacity for self-repair.** The significant alteration of the Valley's groundwater hydrology, the clearing of old-growth forest and consequent loss of the streamflow, groundwater, and habitat-regulating influence of old-growth logs in the stream, and the confinement and simplification of Gold Creek's stream channel represent what science recognizes as the crossing of an ecological threshold. Once such a threshold has been crossed, only active intervention can enable the system to recover anything resembling its fully functional condition for wildlife.[38,98]

Figure 15: September 28, 1983. WSDOT records state that PS-S-156 was last worked on October 5, 1983, so this airphoto shows the site just a week before mining ended, though final reclamation work was not done until 1986. The site of the present-day Gold Creek Pond parking area, not yet developed at the time of the 1977 photo (Figure 14), has been converted into a stockpile site in the intervening years *(aerial image furnished by WSDOT)*.[68]

7. Gold Creek: Past, Present, and Future

"There has never been a more urgent need to restore damaged ecosystems than now."
United Nations Environment Programme (2020).[99]

Ecosystems have long memories. The major natural resource impacts that occurred at Gold Creek over the last two centuries have affected fundamental components of the Valley ecosystem, and the legacies of these disturbances are still with us today. Any one of these impacts – the likely extirpation or near-extirpation of beaver, clearing of the floodplain forest and its old-growth trees, and gravel mining in the stream channel and across a large portion of the floodplain – would by itself be a highly significant blow to any ecosystem. There can be no doubt that the combined impacts of disturbances of these magnitudes have profoundly diminished the Valley's ability to support aquatic and terrestrial wildlife.

Tools for healing a landscape. From an ecologist's perspective, the Gold Creek Valley ecosystem is broken and is functioning only as a small fraction of what it could be. But as concern for the environment has grown, tools have been developed to help broken landscapes heal. The goal of ecological restoration is not to literally return a system to what it once was but to restore ecological functions and habitat qualities where these are impaired, to nudge rivers back towards self-regulation, and to restore the processes by which ecosystems sustain themselves and the wildlife that depend on them.[16, 40] Although every site has its unique challenges and constraints, the tools of ecological restoration have been applied and refined over many years, and an extensive scientific literature testifies to a community of habitat biologists and restoration ecologists that is constantly reviewing, critiquing, and learning from each other's work.

The science of ecological restoration: Professional societies, peer-reviewed journals, and other resources

Society for Ecological Restoration. https://www.ser.org/
Ecological Restoration. Quarterly journal of the Society for Ecological Restoration publishes peer-reviewed scientific papers, professional discussions, news, and reviews related to the science and practice of ecological restoration.
Restoration Ecology. Peer-reviewed scientific journal devoted to original research in the fields of ecological restoration.

Ecological restoration topics are also well-represented in scientific journals that publish a broader range of ecological interests – journals such as *Ecology*, *Ecological Applications, River Research and Applications, Wetlands,* and *Journal of Environmental Management.*.

Add to this a library of scholarly books and practical manuals, plus conference proceedings, webinars, and blogs, and it is clear that the science and practice of ecological restoration is robust.

Cramer, M.L. (ed.). **Stream Habitat Restoration Guidelines** (2012). Co-published by the Washington Departments of Fish and Wildlife, Natural Resources, Transportation, and Ecology.[23]

Dean Apostol and Marcia Sinclair (eds.). **Restoring the Pacific Northwest: The Art and Science of Ecological restoration in Cascadia** (2006).

D.R. Montgomery and others (eds.). **Restoration of Puget Sound Rivers** (2003).[82,96]

Tim Abbe and others. **National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function and Structure** (2016).[18, 43]

Steven Yochum. 2018. **Guidance for Stream Restoration.** U.S. Forest Service, National Stream & Aquatic Ecology Center (2018).

Gary Flosi and others. **California Salmonid Stream Habitat Restoration Manual.** California Department of Fish and Game (2010).

Tools for setting priorities. Another set of tools and processes help public agencies and private conservation organizations to develop an overview of large landscapes so they can set informed priorities about where and how to work at the local, state, and even regional scales. Frameworks and decision-support tools help agencies and private conservation organizations to identify the focal species, habitats, and landscape functions that are critical for the long-term viability of Washington's wildlife and ecosystems. And in the upper Yakima Basin, these conservation frameworks and decision-support tools, described briefly below, point to Gold Creek.

Ecoregional assessments. High-level assessments allow conservation agencies and NGOs to set priorities at a state-wide or regional scale. The Nature Conservancy of Washington and the Washington Department of Fish and Wildlife collaborated on an intensive process to develop conservation strategies – ecoregional assessments (EAs) – for each of the nine ecoregions represented in Washington.[100] The final portfolios of focal species and habitats in each ecoregional assessment are based on lengthy analyses using best available science and comprehensive surveys of technical expert opinions.[101] The upper Yakima Basin is included in the East Cascades Ecoregion, and the East Cascades EA[102] includes Mid-Columbia bull trout and their habitat and Upper Yakima tributaries like Gold Creek among their conservation targets.

The Washington Wildlife Habitat Connectivity Working Group.[29] This working group is a science-based collaborative that includes the Washington Department of Fish and Wildlife, the Washington Department of Transportation, and other state and federal agencies and NGOs that work to identify barriers, such as I-90, to wildlife accessing important parts of the landscape and to develop wildlife passage strategies such as the wildlife underpasses at the mouth of Gold Creek Valley. (We've already discussed the identification of Gold Creek Valley as a key wildlife corridor in Section 3.)

The Cascade Checkerboard Project. The Cascade Checkerboard Project is an initiative to block up strategic former railroad land grant properties that are interspersed in a checkerboard pattern along the former Northern Pacific right-of-way. Led by the Sierra Club[103] and supported by state and federal agencies and by NGOs like Forterra, The Nature Conservancy, Mountains to Sound Greenway, Pacific Crest Trail Association, and others, the Checkerboard Project intersects with a very wide range of public conservation issues including ecosystem function and restoration, forest management, public recreation, endangered species recovery, and wildlife connectivity.

Yakima Bull Trout Action Plan.[104] This joint, science-based effort is led by the U.S. Fish and Wildlife Service, the Washington Department of Fish and Wildlife, and the Yakima Basin Fish and Wildlife Recovery Board to identify key habitats and develop actions for recovery of endangered bull trout in the Yakima River basin.

Actions by public agencies such as the Washington Department of Fish and Wildlife, the Forest Service, and the U.S. Fish and Wildlife Service (USFWS) by law must be guided by the Endangered Species Act. Funding for Forterra's Gold Creek property acquisition in 2008 came, thanks to bull trout, from USFWS's Cooperative Endangered Species Fund.[105]

Upper Yakima Watershed Action Group. The UYWAG is a collaborative group of agency, NGO, and tribal representatives that has been meeting two to three times a year since 2007 to discuss conservation issues in the upper Yakima Basin, and to share information, advise and support, and coordinate activities when possible. UYWAG participants include Conservation Northwest, Washington Department of Fish and Wildlife, Forterra, The Nature Conservancy, U.S. Forest Service, U.S. Fish and Wildlife Service, Yakama Nation, Washington Water Trust, Washington Department of Ecology, Yakima Basin Fish and Wildlife Recovery Board, Mid-Columbia Fisheries Enhancement Group, and others. Gold Creek Valley was one of the first shared priorities arrived at by this group, as much because of its importance as a wildlife corridor as because of bull trout.[106]

Partnerships. Conservation organizations and public agencies work together to advance important conservation and restoration projects. The Restore Gold Creek Coalition includes every public agency and conservation organization that has worked in the Snoqualmie Pass area over the past several decades:

- Conservation Northwest https://www.conservationnw.org/
- Washington Department of Ecology
- Washington Department of Fish and Wildlife
- U.S. Forest Service
- U.S. Fish and Wildlife Service
- Forterra https://forterra.org/
- Mid-Columbia Fisheries Enhancement Group http://midcolumbiafisheries.org/
- Mountains to Sound Greenway Trust https://mtsgreenway.org/
- Washington Water Trust https://www.washingtonwatertrust.org/
- Yakama Nation Fisheries https://www.yakamafish-nsn.gov/
- Yakima Basin Fish and Wildlife Recovery Board https://ybfwrb.org/

What do we do?

The factors that stress our ecosystems and wildlife – habitat loss, human population growth, increasing demands for natural resources, and global warming – are not waiting for us. And they will require of us that we do more than we have done so far, and that we do it faster than we are doing it now if we want to ensure that coming generations can experience the natural wealth that we have today.[107,108]

A restored Gold Creek Valley can help with that.

It’s worth repeating that, acre for acre, healthy riparian ecosystems support more wildlife than almost any other kind of habitat in Washington.[1] Restoration of Gold Creek’s stream channel, riparian vegetation, and their supportive surface and groundwater hydrology would elevate the productivity and biological carrying capacity of the entire Valley ecosystem. While it may not fully restore historical conditions, restoration would increase the resilience of the ecosystem to climate change and would contribute to the function of a critical network of refuges and migration corridors that will benefit many species at a time when they need it more than ever. Gold Creek Valley holds this promise.

I'm neither a fish biologist nor a population biologist, and I'll leave predictions about the fate of bull trout in Gold Creek to the wildlife professionals. But bull trout is just one of the many species in the Valley that would benefit from improved hydrology and instream habitat, and a more productive riparian corridor. A few of the others include caddisflies, Lorquin's admiral butterflies, Cascades frogs, rubber boas, American dippers, yellow warblers, great blue herons, common shrews, Townsend's chipmunks, long-tailed weasels, river otters, bobcats, elk, black bears – the list could go on and on (see, for example, Appendix A).

Habitat restoration carries with it a message of hope – hope supported by science and real-world experience from the Pacific Northwest and around the world. It is an affirmation that we can learn from mistakes and take positive steps to repair the unintended consequences of past actions, that we won't stand passively by while our wildlife populations decline and our ecosystems – and the services and the pleasures they provide to us – continue to be diminished; that we can build or rebuild resilience into our public lands so that they can be vibrant ecosystems not just for today but can enter a stress-filled future in the best condition we can accomplish.

The healthy functioning of our wildland ecosystems is absolutely critical for wildlife and will be even more so in the warmer, drier future we're facing. Those of us lucky enough to be landowners surrounded by key public lands have a special opportunity to participate in efforts to build a more resilient future for our wildlife and our children. We have a responsibility to help ensure that future generations have the chance to experience the wild blessings that we do.

People like us will decide what happens in Gold Creek Valley, but the consequences of our decisions will be borne by Cascade wildlife. We can make a difference, starting today. And if we don't, nobody will.

"From the very beginning of the world, the other species were a lifeboat for the people. Now we must be theirs."

Robin Wall Kimmerer. Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants (2013).[109]

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- 30 years professional experience with The Nature Conservancy, Starflower Foundation, Washington Native Plant Society, National Park Service, and others. Duties included the following:
    - Biological monitoring and assessments.
    - Ecological restoration.
    - Project management.
    - Stewardship of conservation preserves.
    - Data analysis, scientific writing, and professional presentations.
    - Environmental education.
    - Interagency communications and collaboration.
- Belief in science and the scientific review process as the best way society has to seek answers to questions and explore solutions to problems.
- Belief in the mission and science of ecological restoration. Member of the Society for Ecological Restoration since 1998.
- Experience collaborating with state, federal, and tribal agencies to share information and advance shared goals. Worked professionally with a handful of the agency representatives and consultants who have been involved with Gold Creek discussions over the years (most of them are no longer involved).

APPENDIX A. 150 Wildlife Species That Can Benefit from Riparian Restoration in Gold Creek Valley

INTRODUCTION

The Washington Department of Fish and Wildlife estimates that 85% of Washington's wildlife species rely on riparian areas for essential resources during their daily lives or during critical periods of their seasonal or annual life cycles (Knutson and Naef 1997).   Riparian areas that are less productive because of altered habitat structure, hydrology, or other impairment are able to provide vital resources to a smaller range of species and to reduced numbers of the species that are able to persist there.

Listed below are 150 species (or species groups) that are strongly associated with riparian areas in the Cascades and could reasonably be expected to benefit from improved hydrology and stream channel improvements in Gold Creek Valley. The list presents species and groups by life form: insects, amphibians, fish, birds, and mammals. The list is far, far from complete, especially in the insect categories, but I hope will help to provide a wildlife perspective to our discussions about restoration in the Valley.

Although te list includes my personal observations in and around the valley, the great majority of species listed are based on authoritative guides and scientific literature regarding habitats and host plants common to the central Cascades. I've cited these sources at the beginning of each section and in a list of references at the end of the document. A number of the species on the list are already present in Gold Creek Valley, and many others may be present for all we know but at least would very reasonably be predicted to increase if habitat, especially hydrology, is improved. I've been conservative in terms of the larger animals in that I haven't included species like the gray wolf or the fisher, both of which could utilize restored habitat in Gold Creek but which I can't predict will ever get there. Similarly, I haven't included bald eagles or osprey, both of which can be seen occasionally in the Gold Creek corridor but for which I have reasonable doubt that restoration would increase their usable habitat in the Valley itself (I could be wrong). Based on what I know about the habitat needs of snowshoe hare, Douglas squirrels, and northern flying squirrels I couldn't say with confidence that their numbers would increase with improved riparian conditions. The most likely categories for errors would be within the insect groups, which I have only coincidental familiarity with. On the other hand, I've deliberately excluded entire important and species-rich insect groups from the lists for simple lack of expertise and time, and the numbers of species and individuals of insects in healthy ecosystems is so staggeringly high that the numbers provided here are probably underestimates by one or more orders of magnitude. Insects/invertebrates are the primary converters of plant energy into animal energy (which in turn is consumed by larger animals) and thus, after plants, they are at the foundations of nearly all of our ecosystems' food webs.

AQUATIC INVERTEBRATES *(aka. macroinvertebrates)*
(Adams and Vaughan 2003, plus limited personal observations)
Macroinvertebrates are insect species that live most of their lives in the gravels and hyporheic zones of healthy streams, eventually emerging as winged adults who mate, lay eggs back in or near the water, and, usually, die soon after. Robust populations of macroinvertebrates, especially stonefly, mayfly, and caddisfly species, are indicators of good riparian habitat and water quality.

Every one of the listings below represent not a single species but a group of species made up of numbers of related but distinct species, each with their own ecological role. Numbers in brackets ([ ]) are the total number of species in that particular species-group identified by Adams and Vaughn. Even this is a simplification of an extraordinarily diverse order of organisms. A healthy stream may host multiple species from each group but probably not all species in any group.

   

Examples of stream macroinvertebrates. Left to right: stonefly larva, mayfly nymph, case-making caddisfly larva, riffle beetle adult.

Stoneflies (*Plecoptera*) [8]
Mayflies (*Ephemeroptera*) [7]
Case-making caddisflies (*Trichoptera*) [8]
Free-living caddisflies (*Trichoptera*)
Tube- or net-spinning caddisflies (*Trichoptera*) [3]
Alderflies (*Megaloptera*)
hellgrammites (*Megaloptera*)
Dragonflies (*Odonata*)
Damselflies (*Zygoptera*)
Riffle beetles (*Coleoptera*)
Water pennies (*Coleoptera*)
Water mites (*Arachnida*)
Amphipods (*Crustacea*)
Net-winged midges (*Diptera*)
Mountain midges (*Diptera*)
Water-snipe flies (*Diptera*)
Blackflies (*Diptera*)
aquatic sowbugs (*Crustacea*)
crayfish (*Crustacea*)
freshwater snails, limpets, clams (*Mollusca*) [4]

TERRESTRIAL INVERTEBRATES

Terrestrial invertebrates are so numerous as to be overwhelming and are very far from my areas of expertise. To provide some manageable boundaries for this list I've limited selections to species whose larvae feed and develop on riparian trees and shrub. These relationships are often exclusive to a particular tree or shrub species or to a group of related species. Cottonwoods, willows, and alders, species groups strongly associated with proximity to riparian groundwater influence, host disproportionately large numbers of insect species, as suggested by many of the common names below.

Please note that this list does not attempt to include species and groups that do not directly develop as larvae on riparian plants, but which nevertheless strongly benefit directly and indirectly from the productivity of healthy riparian areas. These groups, each of which is represented by many species, include ants, bees, most flies, ground beetles, spiders, and many groups that are less recognizable to us and easily overlooked.

Studies have shown that terrestrial invertebrates make up a significant portion of the diets of salmon and trout (for example Hagar et al. 2012). Terrestrial invertebrates fall in, are blown in, or one way or another end up in or near the water and become important contributions to aquatic food webs. Terrestrial invertebrates, particularly larval or caterpillar stages, are critical foods for resident and migratory songbirds, especially when young are in the nest.

Butterflies & Moths (Pyle 2002, Haggard and Haggard 2006, personal observations)
Lorquin's admiral
Morning cloak
Western tiger swallowtail
Arctic fritillary
Spring azure (on red-osier dogwood)
Sylvan hairstreak
Green comma (green angelwing)
Yellow-spotted tiger moth
Herald moth (*Scoliopteryx libatrix*)
Moon umber moth
Arched hook-tip moth
Willow geometer moth (*Nemoria darwiniata*)
Alder geometer moth (*Sicya crocearia*)
Alder noctuid moth (*Acronicta hesperida*)
Alder looper (*Autographa carusca*)
Cottonwood dagger moth (*Acronicta lepusculina*)
Rusty tussock moth
Enigmantic moth (*Cerastis enigmatica*) - salmonberry
Bruce'sprominent (*Clostera brucei*)
White furcula
Pallid prominent
Black-rimmed prominent
Eyed sphinx moth

Examples of terrestrial invertebrates. Left to right: Lorquin's admiral, green angelwing, cottonwood dagger moth, case-bearing leaf beetle, striped alder sawfly.

Other terrestrial invertebrates (Haggard and Haggard 2006)
Willow twig girdler
Willow flea beetle
Willow leaf beetle
Willow potato gall midge
Willow sawfly (*Trichiosoma Triangulum*)
Willow apple leaf gall
Common willow sawflies (*Nematus chalceus, Nematus iridescens*)
Giant willow leaf gall aphid
Pocket leaf gall aphid
Striped willow leaf beetle (*Disonycha alternata*)
Lang's buprestid
Elderberry long-horned beetle
Twig borer
Alder flea beetle
Alder leaf beetle
Alder stinkbug1 (*Elasmostethus cruciata*)
Alder stinkbug2 (*Elasmucha lateralis*)
Striped alder sawfly
Cottonwood leaf beetle
leaf beetle (*Chrysomela aeneicollis*)
Case bearing leaf beetle 1 (*Cryptocephalus sanguinicollis*)
Case bearing leaf beetle 2 (*Pachybrachis circumcinctus*)
Schaeffer's leaf beetle

FISH (Meyer 2002, USFS 1993, 1998)

Examples of native fish in Gold Creek. Left to right: redside shiner, bridgelip sucker, mountain whitefish, bull trout.

Bull trout	longnose dace
Rainbow trout,	northern pikeminnow
Cutthroat trout	burbot
mountain whitefish	bridgelip sucker
redside shiners	sculpin

AMPHIBIANS & REPTILES (Leonard et al. 1993, Storm and Leonard 1995, limited personal observations)

Amphibians require an aquatic environment for reproduction. Tailed frogs and Pacific giant salamanders remain in or close to water their whole lives, but most amphibians live and forage in uplands once mature, returning to water to breed. Nevertheless, the productivity of healthy riparian areas and wetlands furnishes a concentration of prey organisms closer to rivers and streams. This productivity also favors reptilian predators which may or may not ever enter the water looking for a meal.

Amphibians and reptiles found in Gold Creek and surrounding wetlands. Left to right: Pacific chorus frog, Cascades frog, common garter snake, long-toed salamander.

Pacific chorus frog
Cascade frog
Tailed frog (streams)
Spotted frog
western toad
Pacific giant salamander (streams)
northwestern salamander
long-toed salamander
rough-skinned newt
Common garter snake
Rubber boa

BIRDS (Birdweb no date, ebird Northwest no date, Hagar et al. 2012, Bosakowski and Smith 2002, personal observations)

A few of these bird species rely on fish (heron, kingfisher), insects in the water (American dipper), or prey on small mammals or birds (hawks and owls). All of the rest are heavily reliant on terrestrial insects, especially during the breeding seasons. Most of the migratory species – warblers, thrushes, flycatchers, vireos, swallows, tanager – are exclusively insectivorous and stuff untold numbers of caterpillars and other bugs down the throats of their growing nestlings during spring and early summer. No place is more productive of terrestrial insects than a healthy riparian area, and it's no surprise that study after study has documented a greater abundance of bids in healthy riparian habitats compared to the surrounding landscapes.

Over the last 50 years many of these migratory songbird species have exhibited alarming declines in their numbers (Rosenberg et al. 2019, Sauer et al. 2021). Small songbirds typically survive for only a few years in the wild, and reproductive success is imperative to maintaining their populations. Although long-distance migrants require habitats on two continents plus refueling places during their seasonal journeys, saving or restoring productive breeding habitats in North America is more important than ever for maintaining viable populations of these birds.

Left to right: American dipper (with stonefly larva), yellow warbler, western tanager, Swainson's thrush, Wilson's warbler, MacGillivray's warbler.

In the list below, species in decline across North America (Sauer et al. 2017) are underlined.

Cooper's hawk
Merlin
Great-horned owl
Northern saw-whet owl
Northern pygmy owl
Spotted sandpiper
Ruffed grouse
American dipper
Belted kingfisher
Great blue heron
Downy woodpecker
Red-breasted sapsucker
Rufous hummingbird
Pacific slope flycatcher
Hammond's flycatcher
Dusky flycatcher
Willow flycatcher
Western wood pewee
Black-capped chickadee
Cassin's vireo
Warbling vireo
Pacific wren
Tree swallow
Northern rough-winged swallow
Violet-green swallow
Yellow warbler
Wilson's warbler
MacGillivray's warbler
Yellow-rumped warbler
Yellow-breasted chat
Swainson's thrush
American robin
Western tanager
Black-headed grosbeak
Dark-eyed junco
Song sparrow

MAMMALS (University of Washington no date, personal observations)
Water is the primary habitat for a few mammals like beaver, otters, water shrews, etc., but all mammals in the Cascades require water to survive. As with the other categories of life forms discussed above, healthy riparian areas simply produce more of the food resources different mammal species need, whether that mammal is a consumer of seeds or vegetation, a predator that feeds on those same consumers (or on the abundant insects), or a scavenger that in time may feed on all of the above.

Left to right: northern water shrew, little brown bat, bobcat, long-tailed weasel.

Pacific water shrew
Northern water shrew
Masked shrew
Dusky shrew
Vagrant shrew
Shrew-mole
Pacific mole
Little brown bat
Big brown bat
Silver-haired bat
Hoary bat
Long-eared myotis
Little brown myotis
Long-legged myotis
Beaver
Porcupine
Townsend's vole
Water vole
Black-tailed deer
Elk
Coyote
Bobcat
Cougar
Black bear
River otter
Long-tailed weasel
Short-tailed weasel (ermine)
American (pine) marten

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USFS (United States Forest Service). 1998. **Gold Creek Stream Survey Executive Summary.** United States Department of Agriculture, Mount Baker Snoqualmie National Forest.
These two U.S. Forest Service documents were shared with me through a public documents request. I'll be happy to email a PDF to anyone on request.

University of Washington, Burke Museum of Natural History. **Mammals of Washington.** https://www.burkemuseum.org/collections-and-research/biology/mammalogy/mamwash/index.php

PHOTO CREDITS
Photos are by Jim Evans and family, except as indicated below.

Aquatic invertebrates
riffle beetle adult: Ed Engelman, Flickr.com

Terrestrial invertebrates
cottonwood dagger moth: Fontanelle Forest Naturesearch
case-bearing leaf beetle: iNaturalist
striped alder sawfly: iNaturalist

Fish
redside shiner: Encyclopedia of Life
bridgelip sucker: Challis Messenger
mountain whitefish: Idaho Dept. of fish and Game.
bull trout: U.S. Fish and Wildlife Service

Amphibians & Reptiles
[All photos by Jim Evans and family]

Birds
American dipper (w/ stonefly): National Audubon Society/ Donald M. Jones, Minden Pictures
yellow warbler: U.S. Fish and Wildlife Service
western tanager: Robert Teagardin
Swainson's thrush: Carnegie Museum of Natural History
Wilson's warbler: Peter Pearsal/ U.S. Fish and Wildlife Service
MacGillivray's warbler: Seattle Audubon BirdWeb

Mammals
northern water shrew: Robert Ivens, Flickr.com
bobcat: Paula Rustan
long-tailed weasel: Missouri Dept. of Conservation

APPENDIX B. Pacific Northwest and Global Wildlife in Peril in the 21st Century

INTRODUCTION
There is a growing consensus among the world's scientists that, at every important scale – that is, globally as well as here in the Pacific Northwest -- ecosystems and their wildlife – globally and here at home -- are facing existential threats from a multitude of causes. Although the progressive extinctions of rare species will always be a concern, recent studies show alarming declines in the abundance -- that is, the absolute number of animals -- of common species such as meadowlarks, red-winged blackbirds, many species of frogs and salamanders and mule deer. So far wildlife losses are mainly due to habitat loss or degradation, although toxic pollution, overharvest, and disease are contributors. Global warming has started to aggravate these existing threats but is still far from the most important cause of stress.

Most of us have not had easy access to information that details the severity of this crisis. What follows below is a selection of scientific papers and reports from peer-reviewed scientific journals and other highly respected sources that provide overviews – just the tip of the iceberg -- of some of these threats. Where I could find them I've included newspaper or magazine articles that provide easier-to-read accounts of the same information, but the information in all cases is based on accepted scientific findings. Everyone in the Pacific Northwest has heard about the ominous declines of salmon and their relatives, and I haven't included anything specifically about fish and other organisms in the marine and freshwater environments. Literature detailing the decline of these species and species groups is extensive.

The picture these accounts present are not the anxieties of a few individuals but are a consensus of the world's leading ecologists and conservation biologists. Many researchers say that quick and effective actions to save and restore habitats (and to relieve other threats) can still avert the worst of the impacts we are seeing. But the clock is ticking, and events will not wait for us. What WE act upon to save today is what has a chance to be saved for the future.

GLOBAL WILDLIFE
Ceballos, G., P.R. Ehrlich, and P.H. Raven. 2020. **Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction.** *Proceedings of the National Academy of Sciences* Volume **117, pages** 13596-13602. https://www.pnas.org/content/pnas/early/2020/05/27/1922686117.full.pdf

Díaz, S., J. Settele, E. Brondízio, and many others. 2019. **Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.** Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. 39 pages. https://www.biologicaldiversity.org/programs/biodiversity/pdfs/Summary-for-Policymakers-IPBES-Global-Assessment.pdf

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. 2019. **UN Report: Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating.'** https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

Ceballos, G., P.R. Ehrlich, and R. Dirzo. 2017. **Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines.** Proceedings of the National Academy of Sciences Volume 114, Pages E6089-E6096. https://www.pnas.org/content/pnas/114/30/E6089.full.pdf

Newspaper and magazine articles
Carrington, D. 2020. **Sixth mass extinction of wildlife accelerating, scientists warn.** *The Guardian*, June 1, 2020. https://www.theguardian.com/environment/2020/jun/01/sixth-mass-extinction-of-wildlife-accelerating-scientists-warn

Nuwer, R. 2020. **Mass extinctions are accelerating, scientists report.** *Seattle Times*, June 2, 2020. https://www.seattletimes.com/nation-world/mass-extinctions-are-accelerating-scientists-report/

Fears, D. 2019. **One million species face extinction, U.N. report says. And humans will suffer as a result.** *Washington Post*, May 6, 2019. https://www.washingtonpost.com/climate-environment/2019/05/06/one-million-species-face-extinction-un-panel-says-humans-will-suffer-result/

Carrington, D. 2017. **Earth's sixth mass extinction event underway, scientists warn.** *The Guardian*, July 10, 2017. https://www.theguardian.com/environment/2017/jul/10/earths-sixth-mass-extinction-event-already-underway-scientists-warn

BIRDS

Since 1970 the number of birds -- primarily songbirds -- in North America has declined by nearly one-third, -- three billion birds -- primarily due to habitat loss.

Rosenberg, K.V., A.M. Dokter, P.J. Blancher, J.R. Sauer, A.C. Smith, P.A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P.P. Marra. 2019. **Decline of the North American avifauna.** *Science* 366: 120-124. https://science.sciencemag.org/content/sci/366/6461/120.full.pdf

Newspaper and magazine articles:
Daley, J. 2019. **Silent Skies: Billions of North American Birds Have Vanished.** *Scientific American*, September 19, 2019.

https://www.scientificamerican.com/article/silent-skies-billions-of-north-american-birds-have-vanished/

Axelson, G. 2019. **Vanishing: More Than 1 in 4 Birds Has Disappeared in the Last 50 Years.** Living Bird Volume 38 (4), Autumn 2019. https://www.allaboutbirds.org/news/vanishing-1-in-4-birds-gone/

For more visually inclined people there's this short video:
3 Billion Birds Lost. Video (00:02:49).
https://www.youtube.com/watch?v=cdzU84AyCdI

INSECTS

Insects are underappreciated but are near to the foundations of the food webs and energy processing in every ecosystem, and many beneficial species are important pest-control contributors to our agricultural systems. Many important insect species and species groups around the world are exhibiting significant population declines, raising serious concerns for the many functions and services these groups provide to ecosystems and people.

Wagner, D.L., E.M. Grames, M.L.Forister, and D. Stopak. 2021. **Insect declines in the Anthropocene: Death by a thousand cuts.** Proceedings of the National Academy of Science 118: e2023989118. https://www.pnas.org/doi/10.1073/pnas.2023989118

Sánchez-Bayoa, F., and K.A.G. Wyckhuys. 2019. **Worldwide decline of the entomofauna: A review of its drivers.** *Biological Conservation* 232: 8-27. https://reader.elsevier.com/reader/sd/pii/S0006320718313636?token=28D1E3E3D64965B12D1D449FE76BCC6E9B36863E610EF229CB477170632C5EDB3BFF08B08E796E9B35BE7BAB72FBE442

Newspaper and magazine articles:
Carrington, D. 2019. **Plummeting insect numbers 'threaten collapse of nature.'** *The Guardian*, February 10, 2019.
https://www.theguardian.com/environment/2019/feb/10/plummeting-insect-numbers-threaten-collapse-of-nature

Elizabeth Gamillo. 2021. **As wetland habitats disappear, dragonflies and damselflies are threatened with extinction.** Smithsonian Magazine, December 20, 2021.
https://www.smithsonianmag.com/smart-news/dragonflies-and-damselflies-are-threatened-with-extinction-as-wetland-habitats-disappear-180979260/

AMPHIBIANS

Amphibians – frogs, toads, and salamanders -- are highly sensitive to pollutants, changes in hydrology, and changes in climate, and are considered the most threatened class of animals worldwide. More than a third of amphibian species are at high risk of extinction. Loss of wetland breeding habitats, the breaking of migration connections between wetland breeding habitats and upland foraging and hibernation areas, and novel diseases are among the contributing factors.

Luedtke, Jennifer A., J. Chanson, K. Neam, and over 100 other co-contributors. 2023. **Ongoing declines for the world's amphibians in the face of emerging threats.** Nature, Volume 622, pages 308–314. https://www.nature.com/articles/s41586-023-06578-4.pdf

Cushman, S.A. 2006. **Effects of habitat loss and fragmentation on amphibians: A review and prospectus.** Biological Conservation, Volume 128, pages 231–240. https://www.fs.usda.gov/rm/pubs_other/rmrs_2006_cushman_s001.pdf

Becker, C.G. C.R. Fonseca, C.F.B. Haddad, R.F. Batista, and P.I. Prado. 2007. **Habitat split and the global decline of amphibians.** Science Volume 318, pages 1775-1777. https://www.science.org/doi/10.1126/science.1149374 [Abstract only.]

Newspaper and magazine articles:

Margaret Osborne. 2023. **Amphibians are in Decline Across the Globe.** Smithsonian Magazine online, October 13, 2023. https://www.smithsonianmag.com/smart-news/amphibians-are-in-decline-across-the-globe-180983074/

Lynda V. Mapes. 2009. **Sprawl flattens frogs, other amphibians struggling to survive.** *Seattle Times*, January 21, 2009. https://www.seattletimes.com/seattle-news/sprawl-flattens-frogs-other-amphibians-struggling-to-survive/

HABITAT TYPES

Forests. *Overall, forests support more of the earth's biological diversity than any other habitat type. High rates of degradation and loss of forest area is accompanied by losses of entire, often interdependent, groups of species dependent on forest habitats.*

United Nations Environment Programme. 2020. **The State of the World's Forests: Forests, Biodiversity, and People.** Executive Summary. https://www.unenvironment.org/resources/state-worlds-forests-forests-biodiversity-and-people

Rivers and streams. *Rivers and streams, along with their floodplains and riparian (streambank) areas, provide critical habitat for large numbers of wildlife species, from tiny insects to large mammals. Nearly half of our nation's rivers and streams are rated as being in poor biological condition, with only 28% rated in good condition. Causes are many, but include overlogging of riparian and floodplain forests, dams, incompatible development, and chemical and nutrient pollution.*

U.S. Environmental Protection Agency. 2016. **The National Rivers and Streams Assessment 2008/2009.** Fact Sheet. https://www.epa.gov/sites/production/files/2016-03/documents/fact_sheet_draft_variation_march_2016_revision.pdf

U.S. Environmental Protection Agency. 2016. **The National Rivers and Streams Assessment 2008/2009. A Collaborative Survey.** Full report, EPA/841/R-16/007. https://www.epa.gov/sites/production/files/2016-03/documents/nrsa_0809_march_2_final.pdf

Wetlands. *Wetlands support wildlife in numbers disproportionately greater than the land area they cover. Wetlands also capture and sequester huge amounts of carbon, which is released back into the atmosphere when a wetland is drained or converted to other uses. Thirty-five percent of the world's wetlands are estimated to have been lost just since 1970. The 48 lower United States lost more than 50% of its wetlands between 1780 and 1980. Washington state is estimated to have lost more than 30% of its wetlands during this period (Puget Sound has lost up to 50%).*

Convention on Wetlands. 2018. **Global Wetland Outlook: State of the World's Wetlands and their Services to People.** Secretariat of the Convention on Wetlands, Gland, Switzerland. 86 pages. https://www.ramsar.org/sites/default/files/documents/library/gwo_e.pdf

Dahl, T. E. 1990. **Wetlands Losses in the United States, 1780's to 1980's.** Report to Congress. U.S. Fish and Wildlife Service, Washington, DC. 13 pp. https://www.fws.gov/wetlands/Documents/Wetlands-Losses-in-the-United-States-1780s-to-1980s.pdf

Dahl, T.E. 2000. **Status and trends of wetlands in the conterminous United States 1986 to 1997.** Report to Congress. U.S. Fish and Wildlife Service, Washington, D.C.82 pp. https://www.fws.gov/wetlands/documents/Status-and-Trends-of-Wetlands-in-the-Conterminous-United-States-1986-to-1997.pdf

[Wetland habitat continues to be lost at significant rates since the above reports were published. See https://www.fws.gov/library/collections/wetlands-status-and-trends-national for the latest reports (through 2009)]

WILDLIFE AFFLICTIONS

A number of afflictions active over broad areas have added to the stresses on North American wildlife populations in recent years. In some cases, such as hair-loss syndrome in deer and white-nose syndrome in bats, the afflictions are caused by introduced organisms or pathogens; in other cases the causes are poorly understood.

Chronic wasting disease. *Chronic wasting disease is an always-fatal, contagious neurological disease that is affecting large numbers of deer, elk, and moose from the Rocky Mountain states east. Uncertainty about whether the disease can be passed onto humans who consume the meat of affected animals alsso threatens hunting traditions and key wildlife management strategies.*

Burgess, K. 2020. **Chronic wasting disease: How disease is shaping wildlife management.** National Caucus of Environmental Legislators, May 2020. https://www.ncel.net/2020/05/28/chronic-wasting-disease-how-wildlife-disease-is-shaping-wildlife-management/

Cornell University, College of Veterinary Medicine. No date. Chronic Wasting Disease. https://cwhl.vet.cornell.edu/disease/chronic-wasting-disease .

Peterson, C. 2019. **Faced with chronic wasting disease, what's a hunting family to do?** *High Country News* 51 (18): 24-25. https://www.hcn.org/issues/51.18/hunting-faced-with-chronic-wasting-disease-whats-a-hunting-family-to-do

Hair Loss Syndrome. *Hair Loss Syndrome, attributed to at least two species of introduced deer lice, is a lot more serious than it sounds. It has reduced mule deer populations in Kittitas and Yakima Counties by 40-50%.*

Washington Department of Fish and Wildlife. 2009. **Hair Loss Syndrome caused by exotic lice.** https://idfg.idaho.gov/old-web/docs/wildlife/diseaseExoticLiceFacts.pdf

White nose syndrome. *An infection caused by a novel or introduced fungus, white nose syndrome has killed more than 6 million bats in the U.S. since 2006.*

Fenton, M.B. 2012. **Bats and white Nose Syndrome**. *Proceedings of the National Academy of Sciences* 109: 6794–6795. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3344961/

Washington Department of Fish and Wildlife. 2019. White Nose Syndrome in Washington. https://wdfw.wa.gov/sites/default/files/2019-10/wns_fact_sheet_2019.pdf

Cornell University, College of Veterinary Medicine. No date. **White nose syndrome.** https://cwhl.vet.cornell.edu/disease/white-nose-syndrome

APPENDIX C. Natural Systems Design Project Documents

Documents in order by date filed.

Most links will open a document directly in PDF format. Where noted, some documents must be selected from the document list at the bottom of the 'Gold Creek Restoration Project' on the Kittitas Conservation Trust website and will open in MS Word format without a direct link.

French, D., T. Abbe, M. Ericsson, and S. Higgins. 2013.   **Gold Creek Habitat Assessment & Conceptual Design Task 1: Data Inventory & Data Gap Analysis.** Natural Systems Design. May 31, 2013. 17 pages. https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Gold-Creek-Data-Memo.pdf

Abbe, T., and P. Trotter. 2013. **Draft Gold Creek Habitat Assessment Memo.** Natural Systems Design. November 5, 2013. 20 pages. https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Gold-Creek-Habitat-Memo.pdf

Trotter, P.C. 2013. **Synopsis of 2013 Gold Creek Bull Trout Spawning Activity and Nature of Habitat Used.** Natural Systems Design. November 19, 2013. 5 pages. https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Gold-Creek-Habitat-Memo-Addendum.pdf

Abbe, T., and M. Ericsson. 2013. **Draft Gold Creek Hydrologic Assessment Memo.** Natural Systems Design. December 5, 2013. 17 pages. https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Gold-Creek-2013-Hydrology-memo.pdf

[Assessment figures: https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Gold-Creek-2013-Hydrology-figures.pdf]

Abbe, T., and M. Ericsson. 2014. **Gold Creek Hydrologic Assessment Memo.** Natural Systems Design. November 11, 2014. 12 pages. https://www.kittitasconservationtrust.org/projects/gold-creek-restoration-flow-and-habitat/ [*Scroll down the page until you reach the 'Documents' section and the list of documents. Selecting 'Gold Creek 2014 Hydrology Memo' from the list opens the document directly in MS Word*]

[Assessment figures: https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Gold-Creek-2014-Hydrology-figures.pdf]

Abbe, T., and M. Ericsson. 2014. **Gold Creek Geomorphic Assessment Memo.** Natural Systems Design. November 25, 2014. 14 pages. https://www.kittitasconservationtrust.org/projects/gold-creek-restoration-flow-and-habitat/ [*Scroll down the page until you reach the 'Documents' section and the list of documents. Selecting 'Gold Creek Geomorph Memo' from the list opens the document directly in MS Word*]

[Figures accompanying the assessment are at: https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Gold-Creek-Geomorph-Memo-Figures.pdf]

Abbe, T., and M. Ericsson. 2015. **Gold Creek Conceptual Restoration Design Memo.** Natural Systems Design. April 28, 2015. 10 pages. https://www.kittitasconservationtrust.org/projects/gold-creek-restoration-flow-and-habitat/
[*Scroll down the page until you reach the 'Documents' section and the list of documents. Selecting 'FINAL Gold Creek Concept Memo' from the list opens the document directly in MS Word*]

[Design concept figures: https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/FINAL-Concept-Design-Memo-Figures-2.pdf]

Natural Systems Design. 2017. **Gold Creek Instream Restoration Project: Preliminary Basis of Design Report.** 32 pages. https://www.kittitasconservationtrust.org/projects/gold-creek-restoration-flow-and-habitat/
[*Scroll down the page until you reach the 'Documents' section and the list of documents. Selecting 'Basis of Design Report' from the list opens the document directly in MS Word*]

Natural Systems Design. 2017. **Gold Creek Instream Restoration: Preliminary Basis of Design Report.** Appendix A: Preliminary (60%) Design Drawings, Phase 1. https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Appendix-A.pdf

Natural Systems Design. 2017. **Gold Creek Instream Restoration.** Appendix B: Hydraulic Model Results. https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Appendix-B.pdf

Natural Systems Design. 2017. **Gold Creek Instream Restoration Project – Risk Assessment 60% Preliminary Design.** Natural Systems Design. July 20, 2017. https://www.kittitasconservationtrust.org/wp-content/uploads/2018/06/Risk-Assessment-Memo.pdf

APPENDIX D. Detailed Timeline of Investigation, Development, and Reclamation of Pit Site PS-S-156 in Gold Creek Valley, 1958-1986

Except where otherwise noted, the chronology of events that follows is constructed from documents provided by the Washington Department of Transportation (WSDOT) following a Public Documents Request made by this author February 2021. Documents were provided as numerous PDF scans of individual paper documents (identified only by scan number) and, in one case, a 300-page PDF containing dozens of documents in no particular order. A half-dozen photoimages were also provided. Document names shown below were assigned by the author based on dates, form or memo type names (if applicable) and information in the documents themselves. Documents are available to the public via a similar Public Documents Request (https://wsdot.wa.gov/contact/feedback) but are not available online.

August 27-28 1958
Searching for highway construction materials for an anticipated Airplane Curve to Hyak highway project as well as sand for winter traction control, the Washington Department of Highways (WDH) focuses attention on Gold Creek Valley (Figure 1). WDH field staff investigate the stream channel and floodplain in the southwest quarter of Section 11 (where Starwater and STVMA are today). Eight test pits are dug by backhoe to depths of 11 feet in the Gold Creek floodplain. At least two of the pits are dug in the channel of Gold Creek. This area is identified in WDH records as Pit Site PS-S-156 Extension A.

The next day, the WDH crew digs another four test pits in "mucky" soils on Forest Service Land in the northwest corner of Section 14, as well as another pit in the Gold Creek channel on adjacent private land owned by the Nettleton Timber Company. [*WDH Materials Lab Memo, 1960-02-19*; In file: *WSDOT Collected Gold Creek Documents, pp. 254-255*; *Sections 11 & 14 test pits 1958-08-27 & 28*]

Already by this time a large gravel pit, PS-S-5134, dug directly into the stream channel of lower Gold Creek, has been in operation at least since 1954. PS-S-5134 and its associated stockpile areas are active into the early 1960s (Figure 11 in **An Ecologist's Perspective on Restoration in Gold Creek Valley**).

July 9, 1964
Citing "prohibitive restrictions" placed upon proposed gravel mining operations in Section 14 (PS-S-156B) by the Forest Service, WDH abandons plans (temporarily, it turns out) to extract gravel in that part of Gold Creek Valley. [*WDH letter to Wenatchee National Forest 1964-07-09*; In File: *WSDOT Collected Gold Creek Documents, p. 260*]

November 24, 1964
Following a reconnaissance in Section 11 WDH Materials Engineer R.L. Washburn reports suitable materials in the southwest corner of the section owned by the Northern Pacific Railroad, in a 1000' by 300' or larger area centered on the Gold Creek channel. He describes the site as "recent stream deposits of fairly clean sand and gravel. This area appears to be the only suitable

source in the area, and I would recommend its acquisition" pending confirmatory sampling and testing. [*WDH-IDC (Inter-Departmental Communication) 1964-11-24*; In file *WSDOT Collected Gold Creek Documents, pp. 282-283*]

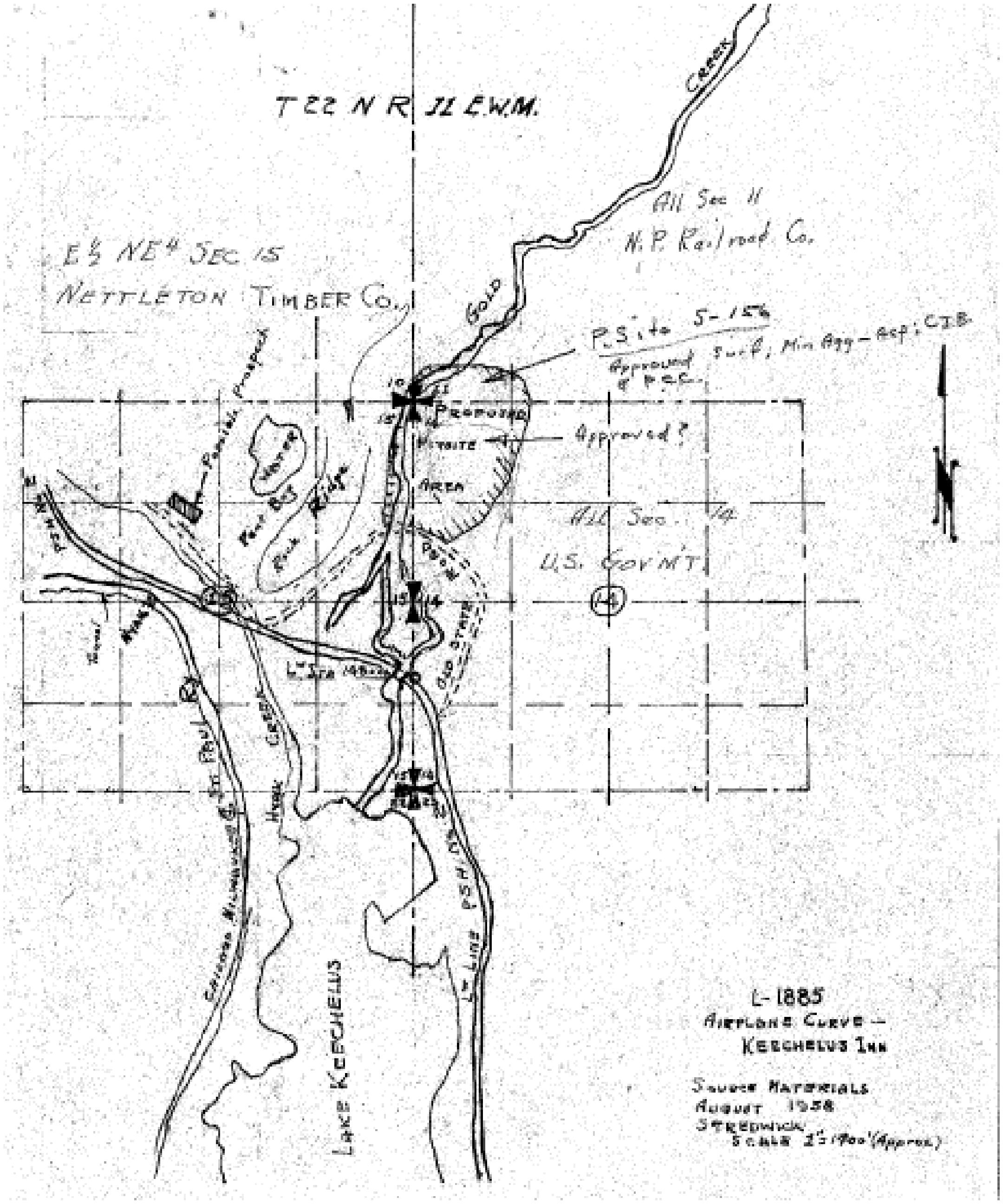

Figure 1. *Sketch map of Washington Department of Highways proposed pit site PS-S-156 in Sections 11 and 14, Gold Creek Valley, 1958. Note the 'old state road' drawn on the map. This was the precursor to the Sunset Highway, which routed up valley to what later became the southern end of the PS-S-156 site, at the southern end of what is now the Gold Creek Pond parking lot, presumably to cross Gold Creek where the channel was narrower than further downstream. This may have been where the bridge depicted in Figure 10 in* ***An Ecological Perspective on Gold Creek Valley*** *was located.* [*Map of proposed PS-S-156 incl. Sect. 11 – 1958*]

July 5, 1966
WDH representatives meet with Bob Hansen, leaseholder in Section 11. WDH reps are encouraged by the meeting with Mr. Hansen, stating "There may be some mutual benefits to the N.P. [landowner Northern Pacific Railroad], Mr. Hansen, and ourselves by a strip [mining] development of the area adjacent to Gold Creek." [*WDH-IDC 1966-07-08*]

September 7, 1966
Still searching for Snoqualmie Pass-area highway construction materials, and with the Forest Service's Section 14 swamp currently (and, as it turns out, temporarily) off the table, WDH conducts material surveys in the southwest quarter of Burlington Northern's Section 11 land.in Gold Creek Valley. The sample area – identified in records as PS-S-156 Extension A – is 200 feet wide by 3300 feet long in the channel of Gold Creek. As part of the survey eight test pits are dug by backhoe in the creek channel. The test pits are 6.5 to 12.5 feet deep and up to 15 feet x 15 feet wide. [*WDH Materials Lab Memo 1966-10-04;* In file: *WSDOT Collected Gold Creek Documents, pp. 198-205*]

While investigating its options in Section 11, WDH continues to be interested in the wetland site on U.S. Forest Service land in Section 14 -- referred to in records as PS-S-156 Extensions B and C -- in the eastern floodplain of Gold Creek. [*WDH-IDC 1967-01-23;* In file: *WSDOT Collected Gold Creek Documents, p. 185*]

October 6, 1967
In a letter to the Forest Service, WDH states that sections 14 and 11 in Gold Creek Valley offer "the only feasible source of Portland Cement aggregate needed for the new highway construction and snow control sand." Noting the Northern Pacific Railroad's intention to plat its ownership in Section 11 for recreational development, WDH asks the Forest Service to reconsider their application to develop a gravel mine in "the swamp area" in Section 14 [*WDH letter to Wenatchee National Forest 1967-10-06*; In file: *WSDOT Collected Gold Creek Documents, p. 177*]

November 30, 1967
In a meeting between WDH and Wenatchee National Forest officials the WNF representatives relay concerns expressed to them by Washington Department of Game (precursor to today's Washington Department of Fish and Wildlife) officials about "fish now spawning in the swamp" at the proposed pit site PS-S-156B on USFS property in Gold Creek Valley. [*WDH-IDC 1967-12-04;* In file: *WSDOT Collected Gold Creek Documents, p. 171*]

April 30, 1968
At a meeting in Wenatchee, Wenatchee National Forest officials agree to issue a permit to WDH for the development of PS-S-156 for materials for the Snoqualmie Summit to Hyak highway project "now being advertised." [*WDH memo 1968-05-14*; *In file: WSDOT Collected Gold Creek Documents, p. 165*]

May 5,1968
In an interview with the Seattle Times Yakima District Highway Engineer G.E. Mattoon states that work on the Snoqualmie Pass to Hyak highway widening "will probably begin about the end of the month or early in June."[1]

May 7, 1968
The initial Special Use Permit for materials extraction at PS-S-156 is granted to WDH by Wenatchee National Forest. The permit states that "Construction or occupancy and use under this permit shall begin within __1__ months." *In other words, use of the site was expected to begin in summer 1968.* The permit also states "All borrow operations will be completed by November 1969." [*WDH-IDC 1970-04-02*; In file: *WSDOT Collected Gold Creek Documents, pp. 130-134*] Although it was understood by both parties that WDH wanted to use the site for at least 5 years and for multiple I-90 projects, the Forest Service stipulated that new permits must be applied for and issued on a project-by-project basis, and this practice is followed through the end of the pit's active life.

Summer 1968
Construction of WDH's Snoqualmie Pass to Hyak project is under way. In mid-July traffic is detoured around the new lane expansion,[2] and in August WDH urged drivers were to seek alternate routes across the Cascades to ease traffic over the pass.[3]

While the initial Special Use Permit stipulated that "Construction or occupancy and use" were to begin in summer, 1968, available documents do not provide conclusive evidence as to whether or not excavation of PS-S-156 was actually begun that year.

Summer 1969
Whether or not excavation was begun in 1968, excavation of PS-S-156 was well-advanced in summer 1969 (Figure 2).

Site development and stabilization included the armoring of the streambank of Gold Creek along the western boundary up to and around the bend of the northwest corner of the site, as well as along portions of the original haul road that bordered Gold Creek. This unnaturally straightened the channel of Gold Creek in this reach and confined the creek to a tiny fraction of its vital floodplain [*WDH memo 1974-04-17* and *WDH letter 1976-11-15*. In file: *WSDOT Collected Gold Creek Documents, pp. 107 and 100 respectively*.

During its period of activity PS-S-156 was not continuously worked but was worked on and off from 1968 or 1969 through the end of operations. Even when gravel was not being extracted part of the site was in active use as a stockpile area for materials previously excavated.

[1] "7th Lane Planned for New Route in Snoqualmie Pass." *Seattle Times*, May 5, 1968.
[2] "Snoqualmie Pass Traffic to 'Narrow.'" *Seattle Times*, July 19, 1968.
[3] "Drivers urged to avoid Snoqualmie Pass." *Seattle Times*, August 21, 1968.

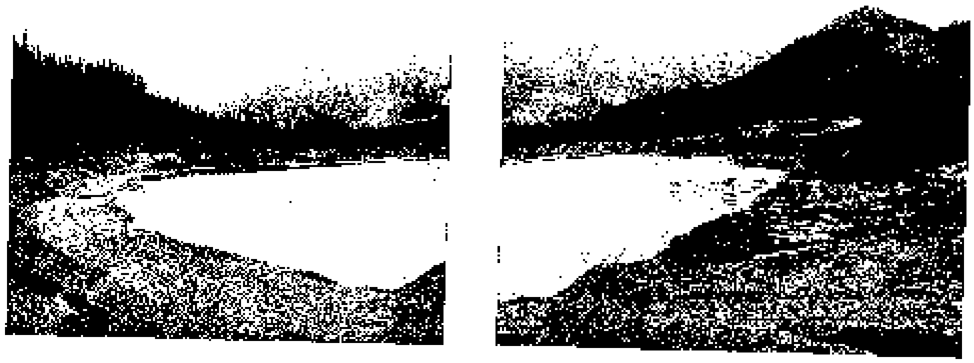

Figure 2. ***Pit Site PS-S-156, 1969*** *(WSDOT). The poor legibility of these images is because WSDOT provided only* *PDFs* *of* *photocopies* *of the original photographs. Nevertheless, a large ponded excavated area, and recognizable topography surrounding the pit/pond site are plain. Inscriptions accompanying the images are as follows (verbatim): Left: "Pit S-156 Ext. looking south from near northeast corner. 1969." Right: "Pit Site S-156 Ext. looking south from near northwest corner, showing dragline operation. 1969." The dragline tower is barely visible in silhouette in this very poor reproduction.*

November 24, 1969
WDH requests the first of a number of extensions of their Special Use Permit. Excavations for a Phase II utilization of PS-S-156 materials for the upcoming "Slide Curve improvement" project were expected to begin as early as summer 1970, suggests that the Snoqualmie Summit to Hyak phase of pit operations was complete by this date (as stipulated in the initial Special use Permit). [*WDH letter to WNF 1969-11-24*; In file; *WSDOT Collected Gold Creek Documents, pp. 140-142.*] but adds no more information regarding the question of whether or not excavation began in 1968.

January 20, 1970
The Wenatchee National Forest issues Amendment 1 to WDH's Special Use Permit for Pit Site PS-S-156, extending the site's activity period through December 31, 1970. [*WNF Amendment Number One 1970-01-20*; In file; *WSDOT Collected Gold Creek Documents, p. 136.*] The granting of amendments extending the Special Use Permit for PS-S-156 became routine through the end of the pit's active life.

October 1972
Congress passes the Clean Water Act.

April 17, 1974
The required reclamation plan for PS-S-156 is revised to change the minimum specification for finished slopes from 2:1 to 3:1 (an improvement but still a very steep slope). [*WDH Reclamation Memo 1974-04-17*; In file: *WSDOT Collected Gold Creek Documents, p. 107; WADNR Surface Mining Report 1998-08-18*]

July 27, 1977

“Pit area is fast becoming exhausted and area is mostly ponds now.” [*WDH Gold Creek Stockpile Site Survey, 1977-07-27*]

September 21, 1977
By an act of the legislature, the Washington Department of Highways becomes the Washington State Department of Transportation (WSDOT).

October 5, 1983
Sixteen years after the initial Special Use Permit was issued, gravel mining at PS-S-156 comes to an end. [*PS-S-156 Pit Eval Report 1987-03-09 – Final*] The forested wetland that once occupied the site has been transformed into a steep-sided, 50-acre pond, with another 30 acres or more of surrounding land heavily disturbed by stockpiles, haul road, and armoring of the Gold Creek streambank along the western boundary of the site.

July 21, 1986
A contract for reclamation work at pit site PS-S-156 is awarded to Dennis R. Craig Construction, Inc. of Redmond. [*WSDOT-IDC 1986-12-04 - project complete*]

October 1986
Reclamation work at PS-S-156 is completed and approved following final inspection. [*WSDOT-IDC 1986-12-04 - project complete; WSDOT Letter to WNF 1986-12-02 - Reclamation completed*]

APPENDIX E. Gold Creek Valley Research & Conservation Action Timeline 1993-2015

Restoration proposals in Gold Creek Valley have been linked to recent regional conservation proposals (for example, the Yakima Basin Integrated Plan), and potential restoration actions in the Valley have been perceived as for the benefit of bull trout alone. But biologists, wildlife agencies, and conservation organizations identified Gold Creek Valley as an area of importance for multiple fish and wildlife species -- not just bull trout -- at least as early as the 1990s.

1992-1993 – Wenatchee National Forest biologists conduct a stream habitat and fisheries survey of Forest Service lands in Gold Creek Valley. In addition to bull trout, fish species detected included rainbow trout and cutthroat trout, mountain whitefish, bridgelip sucker, redside shiners, sculpin, burbot, and northern pikeminnow (USFS 1993, 1998).

1997 – Robert Wissmar and Scott Craig investigate the effects of dewatering on bull trout and other fish in Gold Creek during 1993 and 1994. The researchers estimated mortality of 63% and 24% of spawning BT during the two years, respectively, and discuss the probable effects of the Gold Creek Pond gravel mine on valley hydrology and stream dewatering (Wissmar and Craig 1997).

1998 – The U.S. Fish and Wildlife Service lists bull trout populations in the Columbia River and its tributaries as threatened (USFWS 1998).

2000 – In March, Forest Service researchers Peter Singleton and John Lehmkuhl present the results of their study of wildlife movements across and around I-90, including the Snoqualmie Pass area, identifying lower Gold Creek as a critical link in a key wildlife migration corridor (Singleton and Lehmkuhl 2000).

2000 – U.S. Fish and Wildlife Service biologist Jeff Thomas conducts a study of streamflow and water temperatures in Gold Creek and other tributaries of Lake Keechelus as part of an assessment of habitat suitability for Pacific salmon and bull trout (Thomas 2001). Thomas notes dewatering during August and September but finds that both upper and lower Gold Creek have temperatures favorable for salmon and bull trout, the coolest temperatures of any of the creeks sampled.

2000 -- Central Washington University Master's degree candidate William Meyer investigates bull trout's response to dewatering in Gold Creek and the intensive historic logging, mining, and road building associated with the dewatering, as well as documenting the continued presence of fish species detected during the 1992-93 Forest Service surveys. In his conclusion, Meyer comments that "The persistence of bull trout at sites with these kinds of disturbance patterns is impressive and attests to the resiliency of the species." (Meyer 2002).

2001 – A report to the Washington State Conservation Commission finds that channel widening, the lack of old-growth logs to serve as 'key' pieces for log jams, and the resulting loss of critical habitat features, along with seasonal dewatering, were the primary factors limiting bull trout in

Gold Creek. The report notes that Gold Creek historically supported spawning runs of chinook, steelhead, and coho salmon (Haring 2001).

2002 – A study commissioned by the The Yakima Basin Joint Board, an irrigation utility, determines that Gold Creek and other tributaries above Keechelus Dam have conditions appropriate for several species of Pacific salmon and steelhead (Ackerman et al. 2002).

2002 – The U.S. Fish and Wildlife Service issues a draft recovery plan for bull trout populations in the Columbia River and its tributaries (USFWS 2002).

2007 -- The Upper Yakima Watershed Action Group[4] is formed. The UYWAG is a forum for habitat and wildlife professionals to share information and coordinate efforts to restore aquatic and terrestrial habitats in the upper Yakima basin. Gold Creek is highlighted as one of the group's initial focus areas. Minutes from a 2009 meeting list the Valley's importance as a critical wildlife migration corridor, ahead of bull trout, as a motivation for the group's focus on the valley (UYWAG 2009).

2008 – Using funds from the U.S. Fish and Wildlife Service's Endangered Species conservation Fund, the Cascade Land Conservancy (now Forterra) purchases from Gordon Gray the 240-acre property including Heli's Pond on the east side of Gold Creek upstream from STVMA.

2009 – The Washington State Department of Transportation begins construction on Phase I of the I-90 Snoqualmie Pass East project. In consultation with the U.S. Forest Service, U.S. Fish and Wildlife Service, and a coalition of environmental organzations recognizing the area's importance as a critical north-south wildlife passage, the project includes state-of-the-art wildlife crossing structures including long open spans over the lower Gold Creek floodplain (Washington State Department of Transportation 2021).

2010 -- The Cacade Land Conservancy (now Forterra) sponsors an application for SRFB funding to study and address a suite of factors influencing dewatering and habitat decline in Gold Creek and to develop restoration strategies.

2011 – A Yakima River Basin Water Enhancement Project working group identifies a need for a hydrogeological study and restoration design for Gold Creek bull trout habitat (U.S. Bureau of Reclamation 2011).

2012 – The Yakima Basin Fish and Wildlife Recovery Board publishes The Yakima Bull Trout Action Plan (Reiss et al. 2012). The plan identifies the bull trout population in Gold Creek as a priority for recovery, and identifies creek dewatering and the poor condition of the stream channel and floodplain habitats as areas of greatest concern requiring action in Gold Creek Valley.

[4] Participants in UYWAG include Conservation Northwest, Washington Department of Fish and Wildlife, Cascade Land Conservancy/ Forterra, The Nature Conservancy, US Forest Service, US Fish and Wildlife Service, Yakama Nation, Washington Water Trust, Washington Department of Ecology, Yakima Basin Fish and Wildlife Recovery Board, Mid-Columbia Fisheries Enhancement Group, and others.

2012 – The U.S. Bureau of Reclamation and Washington Department of Ecology issue a Final Environmental Impact Statement for the Yakima Basin Integrated Plan (U.S. Bureau of Reclamation and Washington Department of Ecology 2012). Provisions of the final plan call for assessing and restoring bull trout habitat in Gold Creek.

2012 -- In December the Kittitas Conservation Trust (KCT) is awarded funding by the state Salmon Recovery Funding Board to contract for an assessment of habitat attributes and causes of stream dewatering in Gold Greek (RCO 2015). Early in 2013 KCT contracts with the internationally recognized consulting and engineering firm Natural Systems Design (NSD; https://naturaldes.com/). See Appendix C for a list of and links to NSD assessment and design documents relating to Gold Creek, 2013-2017.

2014 – The Washington State Depertment of Transportation completes the I-90 wildlife undercrossings, near the mouth of Gold Creek (Doughton 2015). Wildlife are documented using the underpasses even before the project is complete, and wildlife usage increases after completion (see https://conservationnw.org/our-work/habitat/i-90/ for articles and videos about wildlife use of the Gold Creek undercrossings to date).

2015 – In January, the U.S. Bureau of Reclamation releases a Draft Environmental Impact Statement for the proposed Kachess Drought Relief Pumping Plant (KDRPP) and Keechelus Reservoir-to-Kachess Reservoir Conveyance (KKC) projects (U.S. Bureau of Reclamation 2015). Appendix C outlines basin-wide recommendations for bull trout enhancement. Higher priority recommendations for Gold Creek include stream channel restoration and a range of options addressing the groundwater draw of Gold Creek Pond. Filling of Heli's Pond is identified as a secondary priority. The Starwater drainage line is mentioned as a contributing factor to dewatering, but specific actions relating to that system are not elaborated on. The document states that "[T]he enhancement projects proposed in this document are separate from the mitigation actions that may be required for the proposed KDRPP and KKC projects."

2015 – In September the U.S. Fish and Wildlife Service issues a recovery plan for all bull trout populations in the coterminous United States (USFWS 2015), superceding the draft 2002 Columbia River plan.

2015 – In December theWashington Salmon Recovery Funding Board awards KCT funding to contract for a preliminary instream restoration plan for Gold Creek, rivermiles 1.0 to 2.1 (RCO 2017).

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