Restoring Anderson Creek

A case history addressing methods for constructing a complex, non-tidal stream channel

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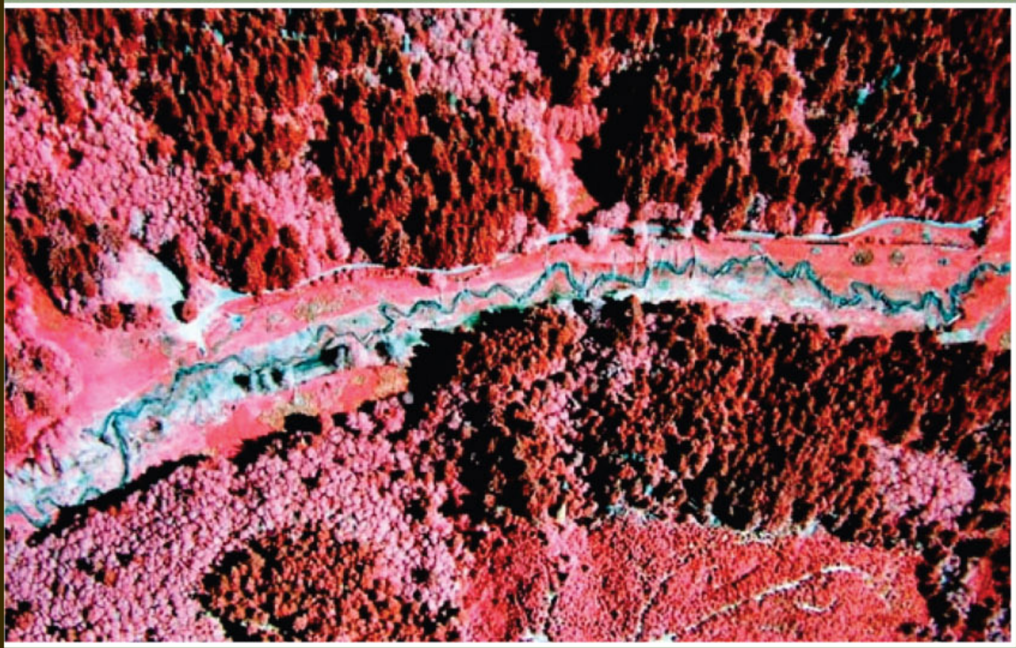


One in a series of three case histories about the South Slough NERR's Winchester Tidelands Restoration Project

PROJECT SUMMARY:

At the South Slough National Estuarine Research Reserve (South Slough NERR), Reserve staff relocated the flow of Anderson Creek from a deeply downcut ditch into a meandering pilot channel to re-establish stream complexity and restore hydrologic connections between stream and floodplain. An extensive planting plan was also implemented to prevent colonization of invasive non-native vegetation and to encourage beaver activity that would continue to add complexity to the floodplain wetlands. Reserve staff determined that constructing a meandering pilot channel is a viable method for creating a new stream channel and that re-establishing such a channel on a floodplain can effectively restore functional hydrological relationships between a stream and its floodplain. As expected, the project caused increases in daily-maximum stream temperatures in the first summer, but these dropped in the second year. Stream temperatures are expected to continue improving as the riparian vegetation develops and shades more of the restored channel. There is currently no beaver activity in Anderson Creek, but Reserve staff anticipate that beavers will colonize the area within the next several years.

BACKGROUND

Downcutting is one of the key challenges that restoration practitioners and land managers must address to restore complexity and wetland functions to altered coastal streams and associated floodplains. Because low-gradient floodplains presented favorable conditions for conversion to agriculture, many complex creek systems were channelized in the early 1900s to drain floodplain wetlands and convert them to pasture (Hopkinson 1993; Bailey et al. 1995; IMST 2002). When complex streams are diverted into straight ditches, their velocity increases, and they cut their channel bottoms downward. Over time, the downcut channels can become so deep that high winter flows can no longer flood over former floodplains. As a result the wetlands' primary source of nutrients can be cut off (IMST 2002). In addition, a downcut channel can dry up the floodplain wetland by draining and lowering its water table especially during summer months. Moreover, the simplified, downcut ditch channels tend to lack beneficial habitat attributes associated with more-complex meandering streams, such as large wood, pools, undercut banks and riparian vegetation.

If no active restoration occurs, a downcut stream will likely continue to erode its channel and ultimately become more entrenched and isolated from its floodplain. In some cases, if beavers re-colonize a downcut stream, there is a chance that their dams could capture sediments and, over time, slowly raise the channel bottom to the point where winter flooding could occur again. However, this process is uncertain and could take decades. In most cases, channelized streams will simply continue to downcut, making passive restoration an impractical strategy.

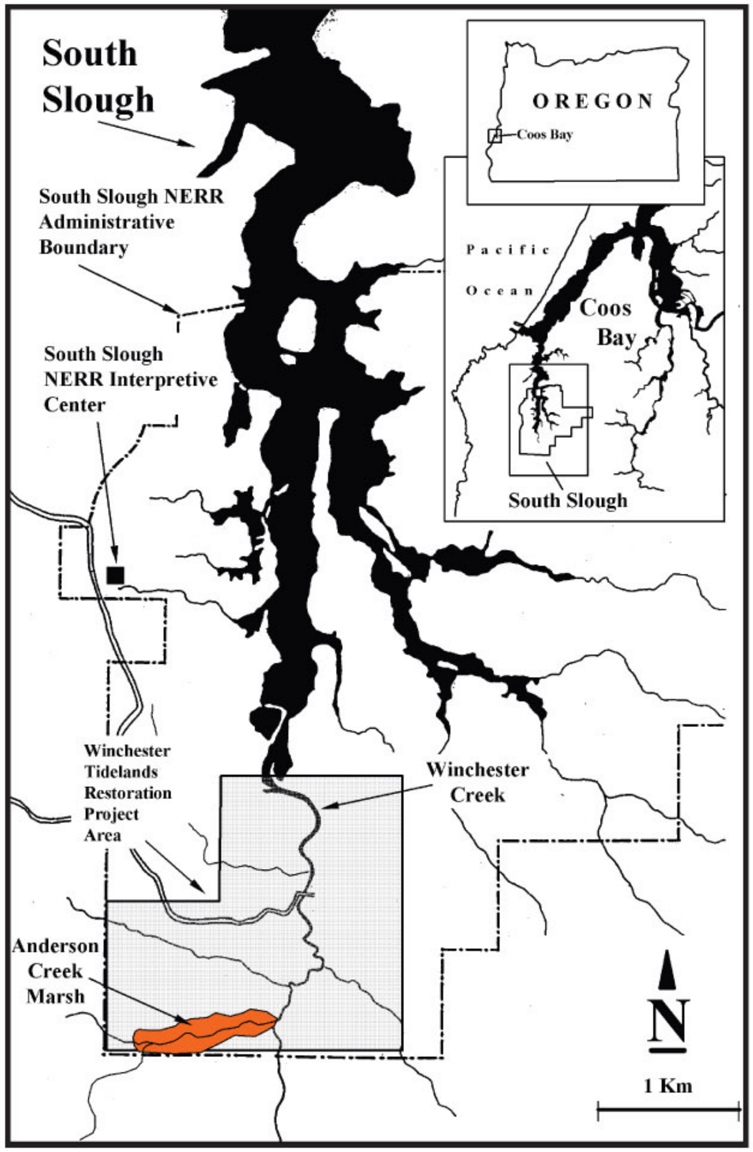


Figure 1. Location of Anderson Creek and South Slough.

After assessing the South Slough NERR's Anderson Creek channel and floodplain, Reserve staff and the Winchester Tidelands Restoration Project (WTRP) Advisory Group (restoration specialists from academic, government, consulting, and non-profit organizations) determined that the site presented a good opportunity to test active methods for re-establishing hydrological connections between a downcut, channelized stream and its floodplain. The WTRP Advisory Group recommended that Reserve staff test restoration methods that could accelerate the development of stream complexity and functions associated with freshwater stream and wetland habitats.

ANDERSON CREEK

Anderson Creek is a small stream located at the head of tide in the upper reaches of the South Slough estuary (see Figure 1). Draining an approximately 100-hectare watershed, the stream is formed by two main tributaries that flow from surrounding hills and join together at the head of a long, narrow floodplain. From there, Anderson Creek once meandered through freshwater wetlands for nearly a kilometer to its confluence with Winchester Creek. In the early 1900s, the floodplain wetlands were converted to farmland, and Anderson Creek was diverted into a straight ditch built along the south edge of the floodplain (see Figures 2 and 3). In addition, a road and a roadside ditch, which captured springs and runoff from the adjacent slopes, were built along the north edge of the floodplain. Riparian vegetation was cleared, and beavers and their dams were removed.

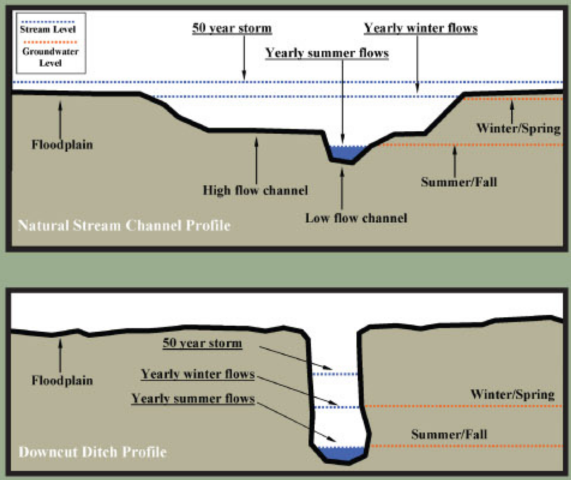
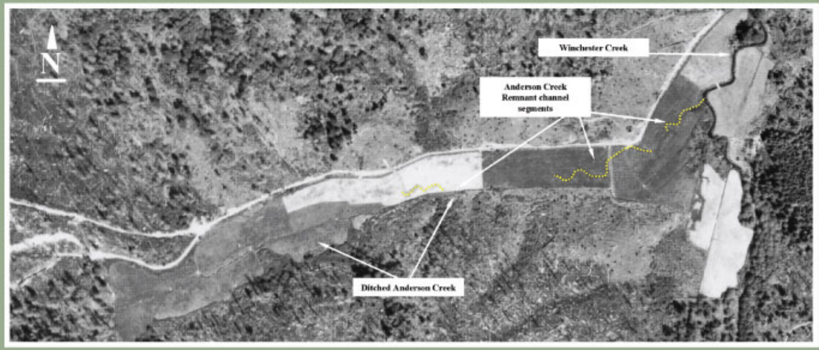


Figure 4. Comparison between a natural stream channel and a downcut ditch. Note the absence of flooding on the ditched floodplain even during a relatively large storm event and the difference in wintertime groundwater levels.



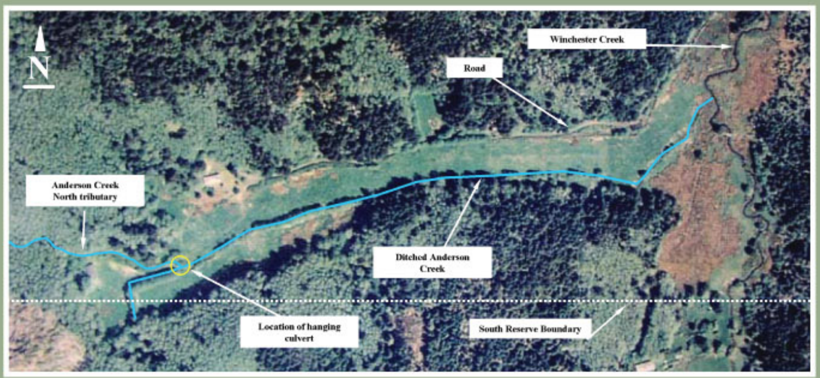


Figure 2. Anderson Creek floodplain in 1939 when the site was actively maintained for farming.

Figure 3. Anderson Creek floodplain in 1991 prior to restoration.

Since farming was abandoned in the 1970s, the simplified ditch had developed some functions found in natural streams and provided some habitat for juvenile salmon, resident fish, and other wildlife, such as crayfish and amphibians. However, there was a hanging culvert perched 2 m above the downcut stream channel that blocked all fish passage to Anderson Creek's north tributary. Downstream of the culvert, intensive downcutting of the channel—more than 2 m in some places—and lateral erosion, or "banging" of the ditch banks by the stream during high flows, contributed to persistent downstream turbidity. Deeply entrenched in the ditch, Anderson Creek no longer had any functional relationship with its floodplain (see Figure 4).

SELF-DESIGN AT ANDERSON CREEK

By re-establishing key physical elements at a site, restoration practitioners can set the stage and then allow natural processes to finish the work of restoration. This strategy is called "self-design" (Mitsch 2000). The self-design approach has the dual benefits of encouraging the development of more-naturally formed features and habitats and also of being more cost-effective than conventional engineering approaches because natural processes rather than earthmoving equipment do most of the work.

At Anderson Creek, Reserve staff planned to re-establish critical structural elements—a new channel and native vegetation—and then to allow natural processes to finish the work of restoration. With a pilot channel, large wood, and native vegetation in place, high winter stream flows would shape the form, size, and complexity of the channel. Over time, the desired stream attributes once abundant in coastal creeks—deep pools, riffles, overhanging banks, fallen trees, and beaver ponds—would also develop through natural processes to provide enduring habitat for fish and other aquatic species with minimal, if any, ongoing maintenance. In addition, by redirecting the stream flow back onto the floodplain, Reserve staff raised the water table and successfully restored enduring hydrological connections between Anderson Creek and its floodplain wetlands.

SINUOSITY OF STREAMS

Sinuosity is the measure of the length of a stream divided by the straight-line distance it travels. The more a stream meanders, the greater its sinuosity.

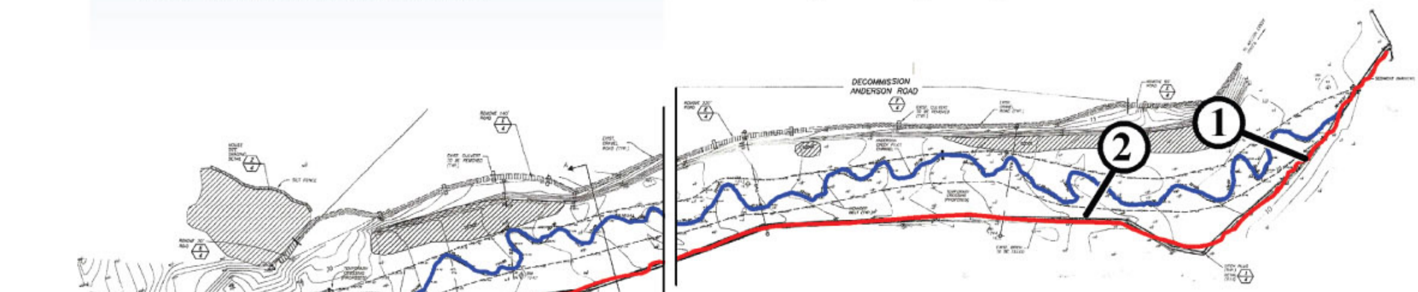
In stream systems, sinuosity is dynamic. When variables such as flow, sediment load, channel slope, amount and type of riparian vegetation, or depth change, a stream adjusts its shape in response. In the Northwest, heavy precipitation from winter storms can boost flows and significantly rearrange stream morphology.

When constructing stream channels for restoration, it is important to design a suitable sinuosity for the new channel but also to recognize that adjustment will occur. At Anderson Creek, the engineer planned for this by constructing a two-tiered channel with a wide meander-belt that could accommodate flows of high-precipitation events.

RESTORATION PLANNING AND METHODS

Redirecting stream flow from the Anderson Creek ditch into a newly constructed channel was at the core of the Anderson Creek restoration strategy. Following self-design principles (see sidebar on previous page), Reserve staff planned to fill the 850-m ditch and to construct a new 1,160-m meandering pilot channel that would return the streambed to an approximation of its historic position on the floodplain and restore lost hydrologic connections between the stream and its floodplain.

To develop an appropriate design for the site, Reserve staff, with the assistance of a Ducks Unlimited (DU) engineer, studied reference sites elsewhere in the South Slough estuary and analyzed aerial photographs of those sites. In addition, Reserve staff had identified in 1939 aerial photos (the earliest set available for the South Slough watershed) faint, remnant patterns on the floodplain surface that indicated the location of short segments of the original Anderson Creek channel. Using stream-geometry measurements from the historic photos and from reference sites, the DU engineer was able to design an appropriate sinuosity, width, meander radius, meander-belt width, and location for the Anderson Creek pilot channel (see sidebar and Figure 5). To plan a suitable channel size, the DU engineer studied historic flow data and calculated channel cross section dimensions for 10-year and 2-year flood events. He then designed a two-tiered pilot channel to accommodate annual high winter flows and low summer flows.



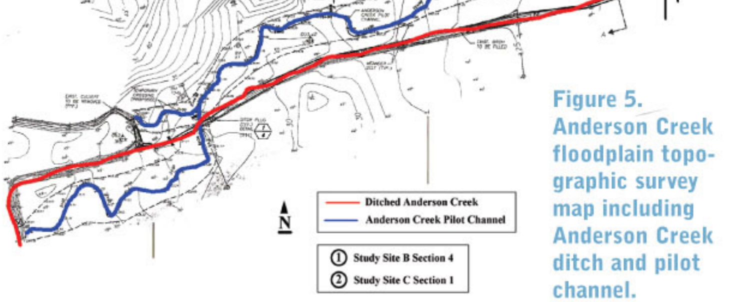


Figure 5. Anderson Creek floodplain topographic survey map including Anderson Creek ditch and pilot channel.

The first phase of project construction began in summer of 2001. To obtain fill material for the ditch and to lay a foundation for stream structure, the contractor re-graded the entire floodplain surface by excavating 20 to 60 cm of topsoil. The new grading would encourage water to concentrate toward the new streambed. All excavated materials were stockpiled along the ditch south of the floodplain to be used later for filling the ditch. The contractor then excavated the pilot channel's first tier, an approximately 5-m-wide and 30-cm-deep high-flow channel that would accommodate annual winter flows (see Figure 6). Because of permitting delays, the project could not be com-

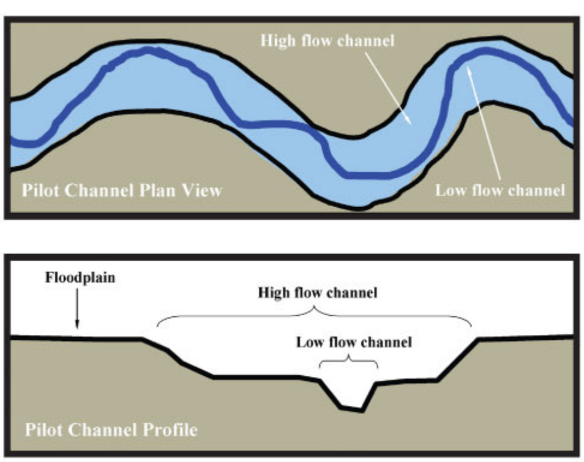
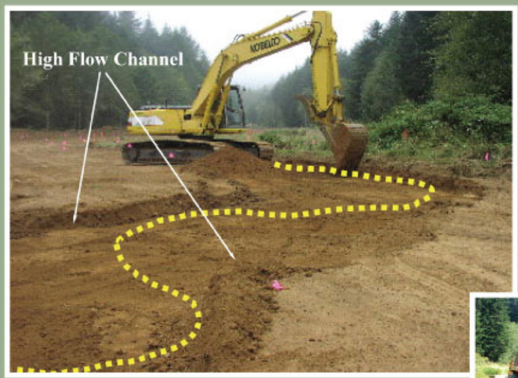


Figure 6. Plan and profile views of the Anderson Creek pilot channel illustrating channel layout and low and high flow channels.

pleted that summer. To protect against erosion over the winter, a sediment fence was installed to prevent runoff from carrying sediment into the ditch. In addition, the entire floodplain was mulched with straw and seeded with tufted hairgrass (*Deschampsia caespitosa*), a native wetland grass, and wheat grass (*Triticum spp.*), a plant that would provide good short-term erosion control but ultimately be out-competed by native vegetation.



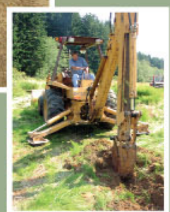


Figure 7. Construction of the high flow channel. Dotted line indicates approximate path of the low flow channel (see insert).

The following summer, the contractor excavated the pilot channel's second tier, a meandering low-flow channel, roughly 60-cm wide and 30-cm deep, within the wider first-tier channel (see Figure 7). The low-flow channel was intentionally under-sized to allow natural processes to shape its final cross section.

Figure 8. Placing large wood in the Anderson Creek channel and floodplain.

To provide additional structure for the developing stream channel, Reserve staff obtained 35 large (0.5 m to 1.0 m in diameter) conifer cull logs from a nearby mill and strategically placed them in and around the pilot channel (see Figure 8). The contractor buried some of the logs just below the stream bottom to prevent the new channel from head-cutting. Others were placed across and along the edges of the channel to encourage the development of scour pools and other structural elements that would increase habitat complexity.

Although improving salmonid habitat was a primary goal of restoring Anderson Creek, there was concern that, in the short term, summer water temperatures would rise too high in the newly constructed channel to support juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Oncorhynchus clarki clarki*). The Anderson ditch, though deeply downcut and lacking the complexity of an undisturbed stream channel, still offered shaded juvenile salmonid habitat. The new channel, on the other hand, would meander down the middle of the Anderson Creek floodplain fully exposed to the summer sun until vegetation could mature and provide shade. In addition, there was concern that sediments released by construction would impair water quality and harm juvenile fish. These concerns were amplified because coho were listed as a federal and state threatened species at the time.

Reserve staff addressed these issues by working with permitting agencies to define the restoration project in terms of its long-term potential to expand and improve stream and floodplain wetland habitat. Reserve staff also developed a plan in cooperation with the Oregon Department of Fish and Wildlife (ODFW) to catch and relocate aquatic wildlife to Winchester Creek before ditch filling. Although there would be some temporary negative impacts to water quality, Reserve staff minimized them and monitored stream temperature, turbidity, and fish use so future restoration efforts could benefit from more-specific data about the duration of habitat impacts resulting from restoration activities.

Accordingly, before the flow of Anderson Creek was directed into the newly constructed pilot channel, volunteers and staff from ODFW and South Slough NERR used electrofishing methods to capture as many fish, amphibians, and other aquatic species as possible out of Anderson ditch and relocated them to Winchester Creek.

In August 2002, the ditch entrance was plugged, and the modest summer flow of Anderson Creek was finally directed into the pilot channel. The parched floodplain soils quickly absorbed the water in the dry pilot channel bottom. Not until the first winter rains did the flow of Anderson Creek make it all the way down to its confluence with Winchester Creek.

The last construction task was filling Anderson ditch. To ensure that the ditch could be fully packed with fill, the contractor first removed the mature red alders (*Alnus rubra*) growing in its bottom. The alders were placed in the pilot channel and dispersed throughout the floodplain to add short-term habitat complexity. (Reserve staff expect that alders will decompose within ten years while the conifer logs will remain in the stream for decades.) The project design called for installation of engineered ditch plugs every 120 m to ensure that water would not be able to flow continuously down the ditch again. To install the plugs, the contractor removed unconsolidated sediments from the ditch and then deposited clean fill material (with no woody debris or vegetation) and compressed it with the track-hoe bucket. The plugs were overfilled by 30 cm to compensate for fill consolidation. The contractor then filled the segments between the plugs with the remaining stockpiled material, again overfilling to offset fill consolidation. The contractor advanced incrementally down ditch: removing and dispersing trees, installing a ditch plug, and filling the area in between plugs. The ditch was filled moving downstream to ensure that it was completely dewatered as the fill was placed.

Figure 9. Anderson Creek floodplain mulched with seedless straw and native slough-sedge hay with ripe seed-heads (inset).

The final component of the restoration plan was planting the site with native wetland and riparian vegetation and controlling invasive species. Because all existing vegetation was removed when the floodplain was graded, Reserve staff expected that the disturbed project area would be particularly vulnerable to invasion by non-native species, including reed canary grass (*Phalaris arundinacea*), bull thistle (*Cirsium vulgare*), Himalayan blackberry (*Rubus discolor*), and others.

In fall 2002, with construction completed, youth crews placed mulch along the pilot channel and floodplain area to reduce erosion and to prepare the area for planting. Two kinds of mulch were used. Commercial straw (seedless) was spread where small-fruited bulrush (*Scirpus microcarpus*) was to be planted, and slough-sedge hay with ripe seed heads was spread where slough sedge (*Carex obnupta*) was to be planted (see Figure 9). The hay was harvested from slough sedge growing in a meadow next to the project area. In winter 2002, with the ditch filled, the water table under the floodplain rose, effectively restoring wetland hydrology to the site (see cover photo).

In February 2003, contractors and work crews began planting two native wetland forbs, slough sedge and small-fruited bulrush, at a 4-to-1 ratio based on plant-community composition at a reference site (see Figure 11). To benefit from the vigor of local gene pools and to reduce costs, the wetland plants and seeds were collected from large stands of sedge and bulrush at the lower end of the project site. Slough sedge was planted in 15 x 15-cm plugs at a 2 x 2-m spacing. Bulrush rhizomes were similarly planted, and bulrush seed was also spread. Native shrubs, including wax myrtle (*Myrica californica*) and evergreen huckleberry (*Vaccinium ovatum*), and upland trees, including cascara (*Rhamnus purshiana*), Sitka spruce (*Picea sitchensis*), western redcedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*), were also planted in high spots along the stream margin and in the floodplain.

In addition, approximately 6,000 willow stakes (*Salix spp.*), cut by contractors and planting crews from local shrub-form willow stands, were planted in a double row along the stream to stabilize the new channel's banks, provide shade, and attract beavers to the project site.

Attracting beaver to the valley was a key strategy of the Anderson Creek restoration plan. Beaver dams and associated ponds were historically common features of low-gradient stream systems in coastal watersheds. By raising the water table and reducing the hydrologic gradient of floodplains, beaver dams slow stream velocity and add complexity and diversity to floodplain wetland habitats. In addition, beaver ponds with their quiet rich waters provide winter rearing habitat for juvenile salmon. By planting willows, one of beavers' preferred food and dam-building materials, Reserve staff intended to recruit beavers to aid in the restoration effort.

In summer 2003, Reserve staff began to implement a three-year invasive, exotic vegetation control program, using methods of hand pulling, mechanized cutting, and careful spot application of an herbicide.

The project's final construction was completed in fall 2003 when the old farm road along the north side of the floodplain was removed. The contractor excavated the top 15 to 30 cm of the roadbed and used the material to fill the ditch along its length and to repair road cut areas from which the material was originally taken. In addition, fill material and old culverts were removed from formerly low wetland areas. Both lowland and upland areas were graded to match adjacent natural contours and then mulched and seeded for erosion control.

MONITORING AND RESULTS

In the years following project construction, Reserve staff collected data at Anderson Creek to monitor channel morphology, vegetation recruitment, water quality, ground water elevation, and fish use.

Channel Morphology

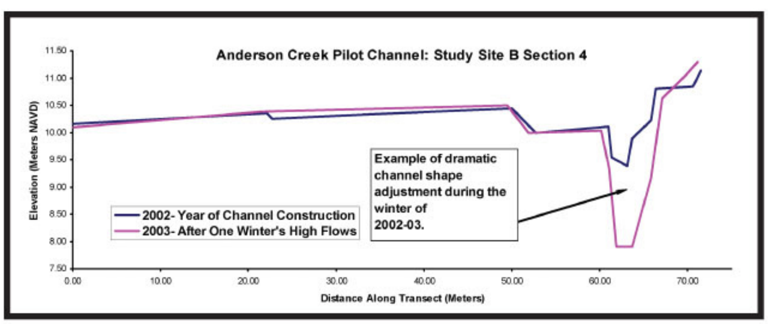
Reserve staff monitored changes in Anderson Creek morphology at ten 30 x 20-m study sites along the channel. At each site, six topographic cross sections were measured across the high- and low-flow channels and a portion of the floodplain. Channel bottom elevations were also measured at approximately 10-m increments to create a longitudinal profile of Anderson Creek and to record changes in channel slope over time.

Figure 10. Planting native wetland and riparian vegetation on the Anderson Creek floodplain.

As anticipated, high flows significantly altered the shape of the new Anderson Creek channel over the first two winters, in part by carrying a large volume of sediment from upstream into the project site. In some stream reaches, this sediment filled up the low-flow channel causing water to overtop its banks and create overflow channels, which carried water during the highest flows and then dried up at lower flows. Some of these overflow channels may turn into more-permanent secondary channels, which can add complexity to the system and may develop into additional aquatic habitat. However, two overflow channels threatened to permanently alter the course of the newly constructed Anderson Creek. In one case, the overflow channel corrected itself after vegetation grew and stabilized banks, and the creek flow remained in the main channel. In the other case, however, it appeared that the overflow channel would bypass much of the complexity designed into the newly constructed Anderson Creek stream channel. Reserve staff decided to intervene and returned the flow of the overflow channel back into the new Anderson Creek channel.

High winter flows also scoured pools, maintained or deepened the low-flow channel in most reaches, and redistributed sediments into bars and riffle formations, often in response to the large wood placed in the channel, thus contributing to the development of complex habitat. Sediment redistribution continued as flow levels dropped in spring and summer. Sediments also accumulated in the high-flow channel and floodplain (see Figure 11).

The cross-sectional shape of the Anderson Creek channel will continue to change in response to the influx of sediments and ongoing hydrologic action until vegetation stabilizes channel banks and limits change in stream morphology to alterations prompted by large precipitation events (IMST 2002).



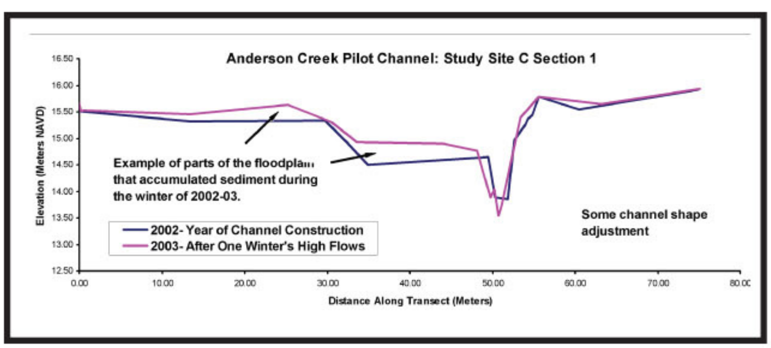


Figure 11. Anderson Creek pilot channel cross sections, in 2002 right after channel construction, and in 2003 after one high flow season (see Figure 5 for locations).

Vegetation Development

To determine if high-density planting of native species will result in the establishment of a native riparian plant community on the floodplain and prevent the colonization of invasive exotic species, Reserve staff are monitoring the development of plant communities at the site. They are collecting data along four transects in the Anderson Creek floodplain to track the presence or absence of emergent plants.

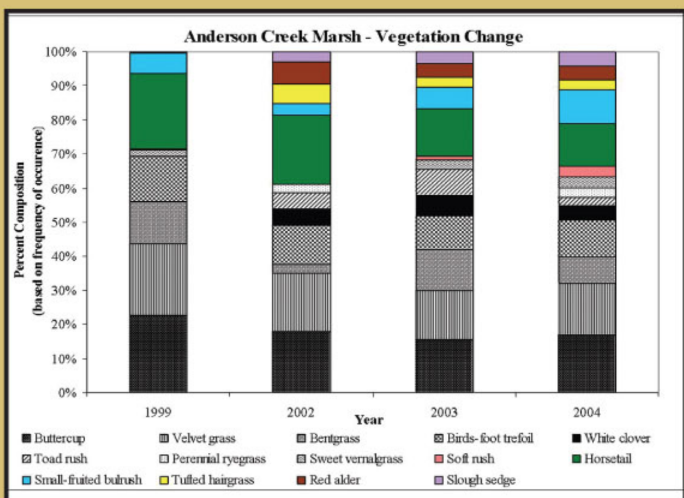


Figure 12. Vegetation change in the Anderson Creek floodplain, 1999 to 2004. Solid colors represent native species. Black-and-white patterns represent non-native species.

In the first growing season (2003), residual pasture grasses and exotic forbs dominated the floodplain. However, there was vigorous growth of the planted slough sedge, small-fruited bulrush, and of soft rush (*Juncus effusus*), a native volunteer (see Figure 12).

By summer 2004, native wetland grasses and forbs had significantly increased in abundance. Small-fruited bulrush had overgrown the banks of the channel and was providing shade for the creek. However, grasses such as velvet grass (*Holcus lanatus*), an introduced pasture grass, persisted in the drier parts of the floodplain.

Most exotic vegetation appearing at the site likely derived from the soil seed bank and was not considered invasive. Over time, most of these exotic species, such as buttercup (*Ranunculus repens*), trefoil (*Lotus corniculatus*), and clover (*Trifolium repens*), will likely be out-competed by the native species, which are more tolerant of wet soils. In addition, Reserve staff expect that beaver activity will ultimately turn much of the Anderson Creek floodplain into a perennially-flooded wetland, further favoring the success of native wetland plants.

However, Reserve staff remain concerned about a few particularly invasive exotic species—Canada thistle (*Cirsium arvense*), bull thistle, and Himalayan blackberry—that could dominate the drier portions of the floodplain if not controlled or eradicated. If the water table can be sufficiently raised by beaver activity, these invasive plants would likely be eliminated. More troubling is reed canary grass, which can out-compete native vegetation even in wet soils. For this reason, Reserve staff are focused on eradicating this species with manual and mechanical removal methods to prevent its establishment at the site.

Water Quality: Temperature, Turbidity, and Bacteria

To determine the short-term effects of pilot channel construction on water temperature, turbidity, and bacteria levels, Reserve staff monitored water quality variables at a series of sites in the Anderson Creek channel.

Water temperature was measured with nine temperature loggers (Onset Computer Corporation, TidBiT® data loggers, ±0.4° F). Temperature loggers were placed at the heads of both tributaries of Anderson Creek above the project area to record temperature before water entered the project site (sites 1 and 2 in

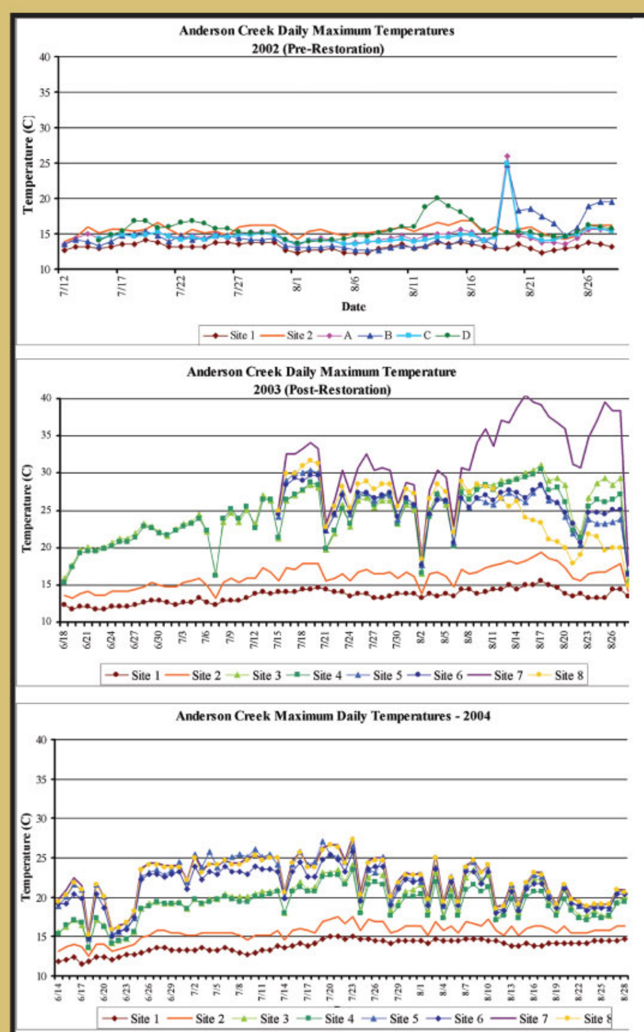


Figure 13. Temperature change in the Anderson Creek pilot channel, 2002 to 2004. Temp loggers 1 and 2 were placed upstream from the project area. Temp loggers 4, 5, 8 were located in pool sites; 3, 6, 7 in riffle sites. Temp loggers A-D were located in the Anderson Creek ditch before filling.

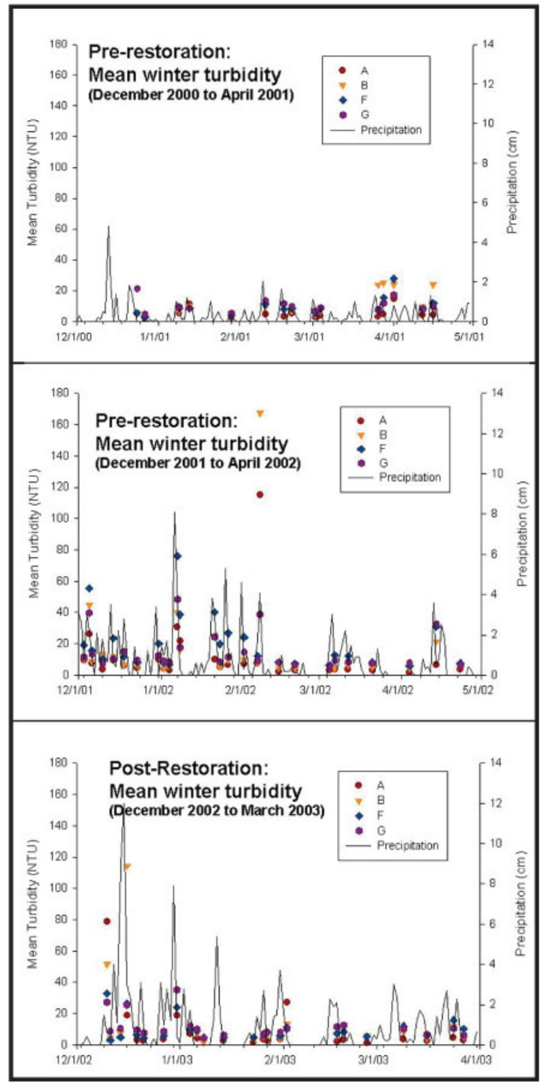
Figure 13). The remaining temperature loggers were placed in pairs in pools (potential summer rearing habitat for salmonids) and in adjacent shallow riffles in the new Anderson Creek channel. To ensure accuracy, TidBiT temperatures were compared monthly with temperatures taken at each location using a National Institute of Standards and Technology (NIST) thermometer. Temperature was tracked during the warm summer months (June to September), the period when high stream temperatures are most likely to affect juvenile salmonids. The near-term daily maximum stream temperature goal for coho salmon survival in Anderson Creek is 18° C (based on a seven-day average), the maximum temperature that juvenile coho can tolerate for extended periods of time. The long-term maximum stream temperature goal is 16° C identified for optimum juvenile salmonid growth (U.S. EPA 2003).

TURBIDITY

Turbidity occurs when accelerated erosion releases sediments (both mineral and organic particles) that cloud water and reduce clarity. High turbidity can be an important issue in freshwater stream environments. Although episodic erosion and sediment production during seasonal flooding are natural processes that can help to create valuable stream habitat, chronic sedimentation can cloud water and cover gravel beds making them unavailable for invertebrates and spawning salmonids. Sediments can also carry extra nutrients into water, fueling rapid growth of algae. When the algae decompose, the water is stripped of dissolved oxygen, creating conditions inhospitable for aquatic life. Chronic high turbidity in streams can cause physiological stresses or even lethal effects for freshwater fish (IMST 2002).

In estuaries, however, turbidity is less detrimental. Estuaries are, by nature, high-sediment environments. With a continual influx of sediment from marine and upland sources and constant hydrologic action of tides, currents, and wind-borne waves, particles are frequently suspended in the water column. Countering this tendency, when sediments in freshwater enter the estuary and meet salt water, they naturally clump together and drop out of suspension in a process called flocculation. Enduring frequent fluctuations in turbidity, plants and animals that inhabit estuaries tend to be better adapted to turbid waters.

Figure 14. Pre- and post-restoration turbidity values at Anderson Creek. Sample sites A and B are above the project site. Site F is in the lower part of Anderson Creek and site G is in Winchester Creek above its confluence with Anderson Creek.



After one year, average daily maximum stream temperature (measured between July 12 and August 26) increased from 14.7° C in 2002 before project construction to 26.4° C in 2003 after project completion (see Figure 13). As riparian vegetation grew in the second year and shaded more of the Anderson Creek streambed, the average daily maximum temperature dropped to 21.0° C in 2004. Stream temperatures upstream of the project site averaged 15.3° C in 2003 and 2004. Maximum stream temperatures in Anderson Creek are expected to continue declining as the plant community matures and provides additional stream shading.

Turbidity was measured with a turbidometer (Hach 2100P) during precipitation events (≥0.15 cm per day) at five locations: one upstream of the project site, three within the project area, and one downstream from the project. Measurements were taken before project construction which began in 2001, and then again in winter 2002, after the creek was re-routed into the pilot channel and flowed again to Winchester Creek. Turbidity at Anderson Creek sites did not increase even after high-precipitation events (see sidebar and Figure 14).

Reserve staff had concerns that the Anderson Creek Restoration Project might affect water quality by unleashing coliform bacteria into the estuary 1.5 km above the nearest commercial oyster beds. After dike removal at the Kunz Marsh Restoration site, there had been some evidence of elevated coliform bacteria counts (see *Restoring Kunz Marsh* case history). This was likely due to high tidal flows inundating the marsh, which had been heavily grazed by elk for decades. It was not possible to determine whether the bacteria were from animal or decaying-vegetation sources.

In Anderson Creek, Reserve staff found that bacteria levels did not increase except briefly during removal of a beaver dam before the filling of Anderson ditch, which presumably released coliform bacteria associated with beaver feces (see Figure 15).

Groundwater Elevation

Restoration at the Anderson Creek site appears to have raised the water table to levels needed to support wetland vegetation in most areas, but not to the levels observed at the upper Tom's Creek reference site. These results suggest that restoration at the Anderson Creek site is successfully re-establishing the physical soil and water-table characteristics that support wetland functions. However, some portions of the Anderson Creek site remain fairly dry, with water table elevations below the expected range for riparian wetlands. These preliminary results will be useful in evaluating potential adaptive management techniques to further enhance floodplain connectivity.

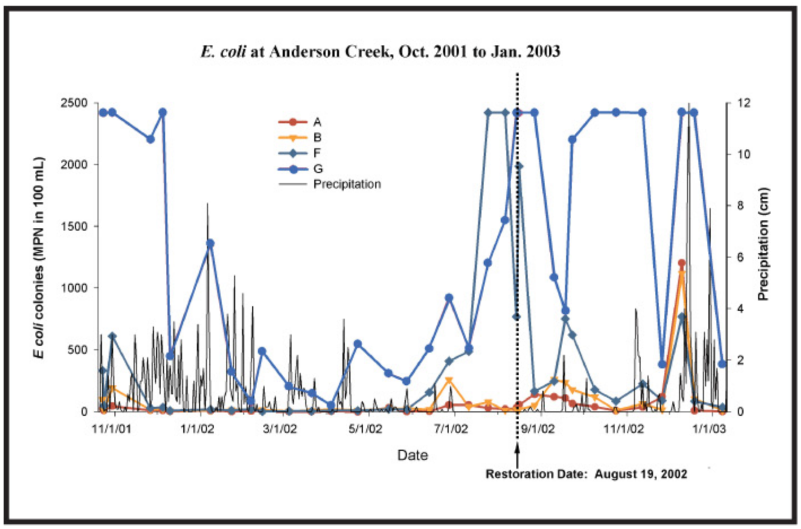


Figure 15. Bacteria (*E. coli*) values at Anderson Creek. Sample sites A and B are above the project site. Site F is in the lower part of Anderson Creek and site G is in Winchester Creek above the confluence with Anderson Creek. (MPN—most probable number—refers to the statistical method used to estimate bacteria colonies)

Fish Use

To determine fish use, South Slough NERR and ODFW staff monitored fish populations at locations most likely to provide habitat for salmonids along the new Anderson Creek channel. Using electrofishing techniques, they sampled at irregular intervals primarily during winter and spring when juvenile salmonids use freshwater creeks as over-wintering habitat.

THE IMPORTANCE OF ESTUARINE HAB

Restoration of degraded estuarine wetlands has become more urgent since scientists have documented the important role of estuarine habitats in the life histories of Pacific salmon. Estuaries provide the salinity gradient necessary for salmon smolts undergoing physiological changes as they migrate from freshwater to saltwater and provide rich foraging opportunities for growth before ocean entrance. For many salmonids, faster growth in the estuary and larger size at ocean entrance have been shown to account for higher rates of marine survival (Reimers 1973; Solazzi et al. 1991).

Juvenile salmonids at different stages of their life histories use diverse estuarine habitats in a variety of ways. In the South Slough estuary, Miller and Sadro (2003) found that both subyearling (the youngest of which are called fry) and yearling juvenile coho used various habitats associated with the upper estuary, but season of use and residence time varied depending on life history stage.

For example, a portion of a newly emerged coho fry population from upper watershed streams may move down into upper estuarine habitats starting in the late winter and early spring. These early migrants use the upper reach of the main channel, where salinity remains low, or move into freshwater tributary streams and associated beaver ponds. During the summer, as salinity intrudes farther upstream and tributary habitats increase in temperature, these subyearling coho may migrate back upstream to seek suitable summer-rearing habitat.

During the following fall and winter when stream flows increase, a portion of subyearling fish from throughout the watershed move downstream

In January 2003, four months after restoration construction was complete, approximately 50 juvenile coho were detected in the lower portion of Anderson Creek. Fish may have migrated into Anderson Creek from Winchester Creek during high water periods resulting from freshets and high spring tides. In summer 2003, many subyearling cutthroat trout and coho were also observed in pools in Anderson Creek.

ITAT FOR FISH

into the upper estuary. This behavior has been documented in other systems as well (Knight 1980; Hartman et al. 1982; Rodgers et al. 1987). Fall and winter migrants may reside in the upper estuary for several months using a variety of habitats, including tributary streams, beaver ponds, the main channel, and fringing marshes during high tide.

Physiological changes associated with the smoltification process begin in late winter and early spring as juvenile coho become yearlings. These fish, called smolts, also use a variety of upper estuarine habitats, but their residence time is shorter, on the order of several weeks. Once fully acclimated to high salinity, smolts are able to use habitats in the lower estuary, but their residence time in this higher salinity habitat is short. Studies of coho smolts tagged with acoustic transmitters in the upper South Slough estuary indicated that fish spent an average of approximately one week or less in the lower estuary before leaving South Slough (Miller and Sadro 2003; Koehler 2003).

These studies suggest that the upper estuary provides critical winter habitat for extended periods and rich foraging opportunities for fish in the smoltification process.

By restoring estuarine wetlands and streams, wetland managers, landowners, watershed councils, and restoration practitioners can provide more winter and summer rearing habitat for juvenile salmonids, including coho. Increased rearing habitat can give more subyearling fish the opportunity to forage and grow before heading out to sea, and would likely result in higher rates of survival.

Sampling in winter 2004 indicated similar numbers of salmonids using the creek as in January 2003, although more juvenile cutthroat trout were observed than juvenile coho salmon. This may indicate that the creek is not yet providing enough of the deep pool habitat that young coho salmon need. Deep pools are especially important for juvenile coho summer rearing habitat. Reserve staff expect that better coho habitat will continue to develop over time as hydrologic action scours pools under buried logs. To further accelerate pool development, during fall 2004, large trees with root wads still attached were airlifted into South Slough NERR restoration sites, including Anderson Creek channel. In addition, youth crews will continue to bury logs in the stream channel to aid in the pool creation process.

LESSONS LEARNED

At Anderson Creek, Reserve staff determined that constructing a meandering pilot channel is a useful method for creating a new stream channel. Reserve staff also determined that redirecting stream flow from a deeply downcut ditch into a meandering pilot channel on a floodplain can effectively restore the functional hydrological relationship between a stream and its floodplain. Following self-design principles in pilot channel construction and planting of native vegetation, Reserve staff were able to ensure development of enduring habitat structures and complexity. So far, robust growth of riparian vegetation overhanging the channel and temperature data have indicated that shaded rearing habitat will likely continue to improve. To date, there is no beaver activity in Anderson Creek, but Reserve staff anticipate that beavers will colonize the area within the next several years.

Although hydrologic action has created pools in the low flow channel, they have not yet developed in the quantity or depth needed for juvenile coho-summer-rearing habitat. This may be due in part to the high clay content of local soils. These soils tend to resist erosion more than others do.

In order to accelerate the development of pools in future projects, Reserve staff plan to try excavating them as part of low-flow-channel construction. Pools will be built in conjunction with large-wood placement to prevent in-filling by sediments. In the absence of wood, pools will be constructed on the outside of meander bends.

Another possible strategy for accelerating pool development is to significantly increase the amount of wood buried in the stream channel. In future projects, Reserve staff will try burying large wood in the bottom of the stream channel to create conditions that encourage pool development through ongoing natural erosional processes.

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GLOSSARY

downcutting: the erosion of a streambed causing a decrease in the elevation of the stream bottom

electrofishing: a method of using a low-voltage wand to momentarily stun fish so they can be netted into a bucket

forbs: herbaceous non-grass plants

head-cutting: an erosional process in which hydrologic action in a stream channel gradually cuts a lower channel bottom elevation for a distance proceeding upstream from a pool

meander belt: the area of the floodplain in which the channel predictably curves and migrates

morphology: the physical shape of the stream channel

pilot channel: a constructed channel intentionally designed to allow hydrologic processes to complete channel shaping over time

reference site: an undisturbed or minimally disturbed landscape that exhibits the structure and functions characteristic of a natural ecosystem and serves as a model for planning a restoration project

salmonids: any fish belonging to the family *Salmonidae*, including salmon, trout, char, and whitefish

sediment fence: a temporary, low fence made of plastic or fabric installed to trap loose sediment and prevent it from entering water bodies

sinuosity: the amount of curvature in a stream channel, calculated by dividing the meandering distance a stream travels by the straight line distance it covers

smoltification: the physiological transformation of young anadromous fish as they prepare to enter the salt water phase of their lives

turbidity: the condition of water with sediment or foreign particles stirred up or suspended; muddy

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