Re-creating Meandering Streams in the Central Oregon Coast Range, USA

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Introduction

For many years, the riparian and stream functions of Bailey and Karnowsky creeks on the Central Oregon Coast Range have been impaired. The valleys were homesteaded in the 1800s; by the early to mid-1900s, both streams were channelized into ditches to increase the amount of land available for pasture. This channelization decreased sinuosity, resulting in increased stream gradients and water velocities. Both stream channels subsequently incised into the easily erodible valley floor. In Bailey Creek, the stream channel started to meander in the ditch, which increased bank erosion and sediment deposition into Mercer Lake. In Karnowsky Creek, larger tributary streams with gradients under 5% were also channelized and downcut to depths of greater than 3 m. These conditions led to a loss of aquatic habitat, disconnected floodplains, lower groundwater tables, and increased bank erosion and sedimentation.

Since 1999, the Siuslaw National Forest and partners have restored the stream channels and valley floor of Bailey and Karnowsky creeks. Lessons learned in Bailey Creek were applied to Karnowsky Creek.

For both streams, we had to answer the questions: What type of stream should we build that will fit the valley type? What should the dimensions of the new channel be, including width, depth, cross-sectional area, gradient, sinuosity, and depth and length of pools? Our project goals included (1) improving coho salmon rearing habitat; (2) reconnecting channels to floodplains; (3) restoring riparian vegetation; and (4) reducing sedimentation. We intended to create channels that are "stable": in other words, they are able to transport the sediment load associated with local deposition and scour while maintaining a consistent channel size and shape (Rosgen 1996). At the same time, we expected lateral migration, via bank erosion and point bar deposition, over time.

Determining the bankfull, or "design," flow was the most challenging aspect of data collection.

This article describes the methods and lessons learned in re-creating two stream channels on the Central Oregon Coast Range.

Bailey Creek Restoration Project

In 1991, the U.S. Forest Service acquired Enchanted Valley in a large land exchange with a timber company; thus, the land changed from private to public ownership. Bailey Creek flows through Enchanted Valley into Mercer Lake, near Florence, Oregon. In 1995, we began the project by gathering data on existing stream conditions. We compared Bailey Creek with a similar coastal stream that had not been cleared and channelized. A topographic map at a 0.3 m (1 ft.) contour interval of the Bailey Creek valley floor was created. Other data collected included several cross-sections of the existing ditch, pebble counts at the cross-section locations, a longitudinal profile of the ditch, and cross-sections and pebble counts upstream from the channelized section. For reference on pre-channelized conditions, we used historical aerial photos (1955) that showed the position, sinuosity, and meander geometry of the original stream channel in the valley above the project area before channelization. Determining the bankfull, or "design," flow was the most challenging aspect of data collection. We determined this parameter via three different sources of information: (1) 16 years of correlated flow measurements to rainfall records (from Giese 1996); (2) measured discharge in the field during winter flow events; and (3) comparison of Bailey Creek to other nearby gauged watersheds.

In our restoration plan, we wanted the new stream to flood frequently during the winter to re-establish seasonal wetland characteristics, and to minimize the risk that the new channel would readjust through bank erosion. We considered designing either a wide, shallow stream (a "C" channel type, width/depth [W/D] ratio > 12, using Rosgen's [1996] terminology), or a narrow, deep channel (an "E" channel type, W/D ratio < 12; Rosgen [1996]). Based on the valley's low gradient, the geomorphic setting (an old lake bed), and reference stream

Table 1. Enchanted Valley specifications

Basin area	11.4 km^2 (4.4 $mi.^2$)
Valley slope	0.34%
Valley length	954 m (3100 ft.)
Streambank substrate	60% silt/clay, 40% sand

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USDA Forest Service

Figure 1. Low-elevation aerial photograph of the new Bailey Creek channel before connection to the old ditch, September 2000.

cross-sections, we chose an "E" channel. To ensure flooding during the winter flows, we designed the new channel's cross-sectional area to be 30% smaller than the existing ditch (Tables 1 and 2).

The design parameters were then translated onto our base map, using a piece of string cut to the length of the new channel at the scale of our map. This method allowed us to easily adjust the proposed location of the stream. We subsequently designed a pool–riffle morphology for the stream bottom, with the pools occupying the outside bends of meanders. The final "string" map was then digitized and put into a geographical information system. Stake co-ordinates were calculated and surveyed onto the ground.

The new 1692 m (5500 ft.) long channel was excavated in late summer 1999 (Figure 1). The outside bends of meanders were revegetated with willow stakes in early spring 2000, and the new channel was connected to the ditch in October 2000. The abandoned ditch downstream of the connection was then intermittently plugged with fill material that was originally stockpiled during channel construction, forming ponds in the unfilled areas. The ponds were located where small tributaries drained off the side slopes, and connected to the new channel. Since then, wood has been added to the channel, and native hardwoods, conifers, and shrubs have been planted in the riparian zone along the new channel.

Karnowsky Creek Channel Restoration Project

Karnowsky Creek, which was acquired by the U.S. Forest Service in 1992, flows into the Siuslaw River estuary between Florence and Mapleton, Oregon. In partnership with the Siuslaw Watershed Council and the Siuslaw Soil and Water Conservation District, we hired a student intern team to develop a whole-watershed restoration plan during the summer of 2001. This team researched watershed history, fish and wildlife habitat, and plant communities, and subsequently drafted a restoration proposal. We used this proposal to apply for funds from the Oregon Watershed Enhancement Board and the National Forest Foundation.

The restoration plan for Karnowsky Creek was similar to Bailey Creek, emphasizing the creation of summer and winter rearing habitat for coho. One heavily aggraded section of ditch that had suitable existing spawning habitat was left to passively recover. In contrast with the Bailey Creek channel design, we relied less on discharge calculations and measurements, and more on bankfull cross-sections in the existing ditch to determine the cross-sectional area of the new channel. We assumed that the ditch

Table 2. Bailey Creek measurements

Parameter	Historic channel	Ditch	New channel
Sinuosity	1.7	1.1	1.8
Gradient	0.22%	0.32%	0.19%
Bankfull width	8.5–12 m (28.5–40 ft.) (based on cross-sections above channelized section)	4–4.5 m (13–15 ft.)	6 m (20 ft.)
Bankfull depth	No information	1.5–2 m (5–7 ft.)	0.9 m (3 ft.) in riffles 1.5 m (5 ft.) in pools
Belt width	68–85 m (220–275 ft.)	Not applicable	46–77 m (150–250 ft.)
Meander length	77 m (250 ft.) (average)	Not applicable	73 m (239 ft.) (average)
Radius of curvature	25 m (82 ft.) (average) 12–43 m (40–140 ft.) (range)	Not applicable	16 m (52 ft.) (average)
Width/depth (W/D) ratio	No information	2–3 in lower valley; 25 above channelized section	7
Cross-section area	No information	8.36 m^2 (90 $ft.^2$)	6.27 m^2 (60 $ft.^2$)
Total channel length	No information	1105 m (3627 ft.)	1692 m (5500 ft.)

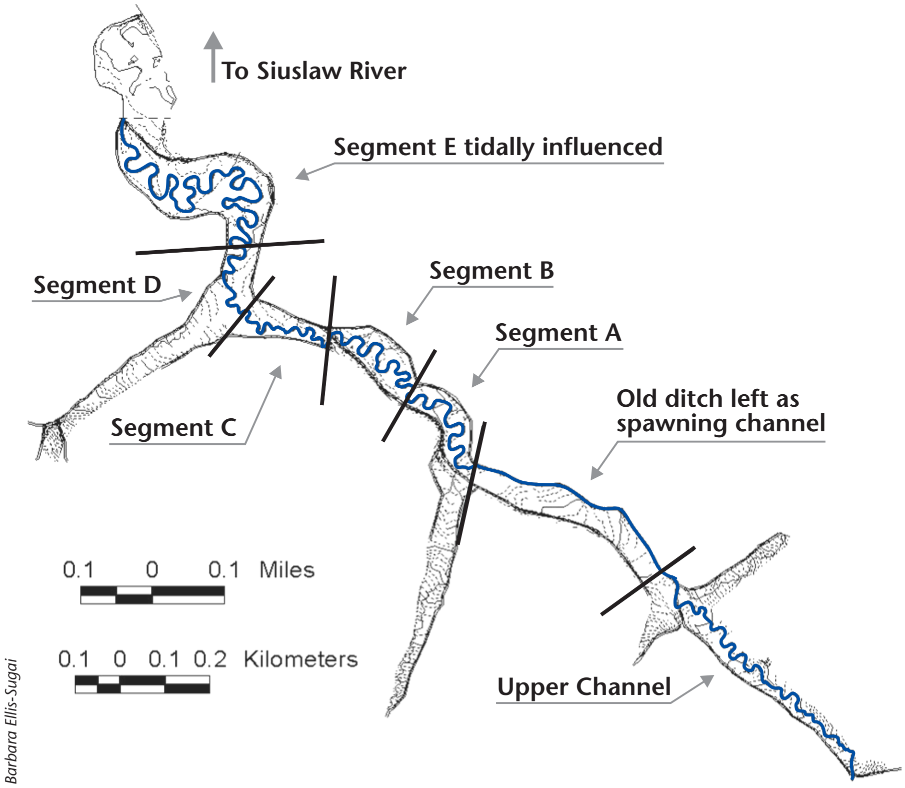

Figure 2. Map of the Karnowsky Creek valley floor and new channel. Key: black, bold solid lines-old ditches; dark blue, bold lines-new channel.

had come into equilibrium with bankfull flows, and would more accurately reflect the new channel's size requirement than flow equations. To cross-check, we calculated the bankfull discharge for the existing ditch and compared it with the new channel using a regional equation for small watersheds developed at Oregon State University (Adams *et al.* 1986), the regional U.S. Geological Survey equations (Jennings *et al.* 1993), and Manning's equation. As with Bailey Creek, we wanted the channel to frequently overtop its banks. Therefore, the new channel's cross-sectional area was designed to be 33% smaller than the existing ditch.

In our restoration plan, we explicitly defined the desired width/depth (W/D) ratio, the slope, and the sinuosity of the new channel. The W/D ratio is important because it is a major control on shear stresses within the channel. To determine whether the stream should be a "C" or "E" channel (Rosgen 1996), we used the W/D ratio from a nearby reference stream (9.5), and referred to Rosgen's (1996) classification system. Unlike the Bailey Creek design, we allowed more variation in the size and shape of the meanders (Williams 1986). We ran several W/D combinations through Manning's equation and shear stress equations to compare the existing ditch's estimated discharge and shear stress with that calculated for the new channel. We chose a W/D ratio of 9.3, a relatively narrow channel. The rationale was that the vegetation on the valley floor will support the higher shear stresses found in an "E" channel, and a narrower, deeper channel would have less direct solar heating. The new channel's dimensions are shown in Table 3.

For Karnowsky Creek, the upper valley is slightly steeper, while the lower, tidally influenced valley has a very low gradient. To fit the valley, we designed the new stream's gradient to gradually decrease from 0.76% at the top to 0.11% in the tidally influenced zone. Likewise, sinuosity increases down valley, from 1.2 to 2.8. In the tidally influenced zone, where frequent winter flooding occurs, we wanted to create diverse fish habitat

As with Bailey Creek, once the slope and sinuosity were established, the new channel was laid out on the base map, and surveyed onto the ground (Figure 2). The survey data for the channel location and existing ground elevations were entered into a spreadsheet. The expected bank heights in the new channel, assuming a constant stream gradient through a reach, were then calculated. The upstream and downstream locations for pools and riffles were added.

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Table 3. New Karnowsky Creek channel dimensions

Channel segment	Width	Riffle depth	W/D ratio	Cross-section area	Gradient (%)	Sinuosity	New channel length
Upper channel	3.1 m (10 ft.)	0.3 m (1 ft.)	10	0.93 m^2 (10 $ft.^2$)	0.76	1.2	684 m (2223 ft.)
A	4.3 m (14 ft.)	0.46 m (1.5 ft.)	9.3	2.0 m^2 (21 $ft.^2$)	0.39	1.9	393 m (1278 ft.)
B	4.3 m (14 ft.)	0.46 m (1.5 ft.)	9.3	2.0 m^2 (21 $ft.^2$)	0.28	2.2	546 m (1773 ft.)
C	4.3 m (14 ft.)	0.46 m (1.5 ft.)	9.3	2.0 m^2 (21 $ft.^2$)	0.38	1.6	356 m (1157 ft.)
D	4.3 m (14 ft.)	0.77 m (2.5 ft.)	5.6	3.3 m^2 (35 $ft.^2$)	0.20	1.6	226 m (733 ft.)
E	4.3 m (14 ft.)	0.77 m (2.5 ft.)	5.6	3.3 m^2 (35 $ft.^2$)	0.11	2.8	1356 m (4406 ft.)

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Figure 3. Construction of the new Karnowsky Creek channel, summer 2002. Stakes in foreground identify the location of a transition from a riffle to a pool. Note the excavated mounds of soil left on the floodplain.

The new Karnowsky stream channel was built in late summer 2002 (Figure 3). In the lower part of the valley, where wet soil conditions persist throughout the year, the excavated material was piled in mounds and shaped on the valley floor. This method reduced both haul costs and potential for soil compaction from dump truck traffic. Mounds also offered high points in the floodplain that provided good planting sites for Sitka spruce and western redcedar. During the first winter after construction, willow stakes were planted in the banks, and trees and shrubs in the floodplain. At that time, water was not flowing in the main channel, which gave the willows a chance to establish.

During the second summer (2003), ditches were plugged in several strategic locations, and water was diverted into the new channel. We applied the lessons learned in Bailey Creek, where we had left an abrupt vertical wall at the connection between the old ditch and new channel. The old ditch was 1 m (3 ft.) below the new channel. We erroneously assumed that sediment would drop out at this point, as water slowed to enter the new channel at a lower gradient, and cause aggradation in the old ditch. However, a tail cut began to develop downstream from this point as the channel's longitudinal profile came into equilibrium between the two elevations. In Karnowsky Creek, the new channel was designed to gradually slope up from the old ditch's bed elevation to the new channel, about a 0.3 m (1 ft.) difference in elevation. A ramp of large logs was buried at grade in the new channel at the connection to prevent downcutting.

In the fall of 2003, 130 large, whole trees were added to the new channel and floodplain by helicopter to provide current and future cover for fish-rearing areas. Based on research by Roelof (2002), who completed the planting plan for the project, we tried to approach 10% coverage of the valley floor with this wood in 3–4 ha less than 2% of the valley floor. Work in three steeper side tributaries and the upper main stem is ongoing, and may supply additional spawning habitat to complement rearing habitat created by the work discussed in this paper. In 2004, the new upper channel was connected to the existing channel, and the ditch in the upper valley was filled in.

Monitoring

Both streams are being monitored with permanent cross-sections, low-elevation aerial photographs, on-the-ground photo points, spawning surveys, juvenile fish counts, and collection of water-quality data. In Karnowsky Creek, a network of groundwater wells is being measured monthly to track groundwater levels.

Results of Restoration

Bailey Creek

The new channel increased channel length by 33% and doubled the pool volume compared with the old ditch. The stream overflows its banks during winter, and the channel appears to be relatively stable, although adjustments are occurring. In some places, point bars and mid-channel bars are being deposited, as expected (Figures 4a and 4b). Since the new Bailey Creek was connected to the existing channel in 2000, U.S. Geological Survey river gauges on the Alsea River to the north, and the Siuslaw River to the south have shown annual peak flows to be slightly below average. The gauge record goes back to 1940 on the Alsea River. No gauges are on nearby streams of comparable size.

J.B. Hogervorst

Figure 4a. New Bailey Creek channel at photo point 7, summer 1999.

Jeff Schmalenberg

Figure 4b. New Bailey Creek channel at photo point 7, summer 2003.

Fish numbers, both returning spawning adults and rearing juvenile coho, have increased. Spawning surveys over the last 4 years indicate a definite increase in numbers, averaging over 322 fish per kilometre (200 fish per mile) compared with an average of 113 fish per kilometre (70 fish per mile) annually during the 4-year period before the new channel was built (1996–1999). The increase from 2002 to 2003 alone was 130 fish per kilometre (81 fish per mile). The 2003 spawning adults were the first juveniles reared in the project area to have returned. The assumption is that juveniles of this year's class took advantage of both favourable conditions in the new channel and the ocean to produce the 2003 spawning numbers. Bailey Creek was one of the few areas where spawning counts increased in 2003. The control data indicate that from 2001 to 2003, the number of juvenile coho was 1.5–2.0 times higher compared with the two previous years' samples. At the same time, there was roughly a 10-fold increase in numbers of juvenile coho in the project area in 2001–2003. For 2003, the control estimate was 0.5 coho per square metre while the project area estimate was 1.1 coho per square metre.

Barbara Ellis-Sugai

Figure 5. The new Karnowsky Creek channel in the lower valley during high winter flows. Conifer seedlings in plastic tubes are planted on the mounds left on the floodplain.

Karnowsky Creek

Although it is too early to have significant monitoring results, we are already seeing abundant coho smolts and fry in the new Karnowsky Creek channel. The channel functioned well through the first two winters, with frequent floodplain inundation. Willows and other riparian vegetation are growing well, and point bars are being deposited on the inside of meander bends in the lower channel. Little, if any, bank erosion is evident (Figures 5 and 6). The mounds built into the floodplain of the lower valley are successful nurseries for young conifers and shrubs.

Future monitoring of fish populations will include summer snorkel counts in pools of the new channel and spot checks of ponds created from the old ditches that were plugged. We considered running a smolt trap for the spring migration, but frequent floodplain inundation, along with lack of funding, labour resources, and research groups prohibits this level of monitoring.

Spawning surveys are also ongoing, particularly in a 0.8-km (0.5-mi.) section of upper main stem that was reconstructed and connected to water in 2004. In December 2004, coho salmon were observed spawning at the top of the upper main-stem channel, just 2 months after that section of the new channel was connected to the existing stream channel.

Summary of Lessons Learned

- Cross-sections of the existing ditch are probably more reliable than regional flow equations or discharge measurements when determining the size of the new channel.
- Creating hummocks in the floodplain aids in re-establishing vegetation in areas infested with reed canary grass, and provides micro-topographic sites. It also saves hauling of the excavated material.
- Grade control and a smooth transition from the existing ditch to the new channel will prevent downcutting in the new channel.

Barbara Ellis-Sugai

Figure 6. The new Karnowsky Creek channel with large wood added, winter 2003. New conifer seedlings are planted along the bank and protected by plastic tubing.

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- These restoration projects require intensive data-gathering and planning by an interdisciplinary team of hydrologists, geomorphologists, fisheries biologists, botanists, and surveyors, and benefit from review by other technical experts.

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Results of Streamline Reader Survey 2004

Robin Pike

THANK YOU to everyone who participated in our reader survey this past fall. The survey was designed to help us assess our performance and, most importantly, solicit your feedback on areas for improvement and suggestions for future articles. Overall, respondents told us that we are on track in presenting objective and reliable watershed management information. Here are the highlights of the survey.

Streamline articles are technically reviewed and those readers polled trust information presented in Streamline.

Of those polled, 42% were unaware that all articles published in Streamline undergo a technical peer review. As a result, we will better communicate the measures we use to ensure that reliable and sound information is extended. Despite this finding, 92% of those surveyed indicated that they either have a lot of trust (25%) or a fair amount of trust (67%) in Streamline. Only 5% of the respondents indicated that they had little trust in Streamline as an information source.

Streamline is relevant, scientifically sound, user friendly, and easy to access. Most readers prefer the current format.

Of those completing the survey, 90% indicated that they prefer the current mix of short newsletter-style and longer technical articles. Preference for print versus online versions of the publication was more evenly split among respondents, with 51% favouring online access, 41% print, and 8% both publication formats. We will seriously consider these data if limited funding in the future does not allow us to produce print versions.

Regarding our publication format, most respondents agreed or strongly agreed that articles in Streamline are relevant and applicable (92%), scientifically sound (82%), readable in style (94%), well laid out (84%), easy

Jack Minard of the Tsolum River Restoration Society, Courtenay, B.C., won our survey draw-prize—a $75 gift certificate to Chapters.

Table 1. Client satisfaction in Streamline's format

Question: In your opinion, are Streamline articles…	Strongly agree (%)	Agree (%)	Neutral (%)	Somewhat disagree (%)	Strongly disagree (%)
1. Relevant and applicable	26	66	7	1	0
2. Scientifically sound	19	63	17	1	0
3. Readable in style	27	67	4	2	0
4. Well laid out	31	53	15	0	1
5. Easy to access	36	56	7	1	0
6. Innovative in content	14	52	30	4	0