Lateral Channel Migration, Downcutting and Restoration Potential of the North Fork Siuslaw River

A report prepared for the Siuslaw River Watershed Council

By

Barbara Ellis-Sugai, PhD
Forest Hydrologist
Siuslaw National Forest

July 2002

Table of Contents

Table of Figures

Plates (Located in Back Pockets)

Lateral Channel Migration, Downcutting and Restoration Potential of the North Fork Siuslaw River

Barbara Ellis-Sugai
Hydrologist
Siuslaw National Forest

January 2002

Introduction

The North Fork Siuslaw River is a major tributary to the Siuslaw River. The confluence is near Florence, Oregon (Figure 1). This study looked at the mainstem from the mouth of the river to just downstream of the North Fork Siuslaw Campground, and the lower portions of McLeod Creek, Condon Creek and Morris Creek.

The purpose of this study is to 1) document where lateral channel migration and bank erosion have occurred, 2) determine whether the apparent downcutting and high river banks are naturally occurring, or the result of disturbances in the valley, and 3) document changes in the riparian vegetation over time.

Methodology

Digital orthoquad aerial photos from 1994 served as the basis for creating maps that show the river's location and the extent of riparian vegetation over time. ArcView™ 3.2a software was used to create and analyze the maps made for this study.

Historic air photos were obtained from the following sources:

- 1937 and 1952 air photos were obtained from the University of Oregon. The 1937 photos only cover the North Fork Siuslaw River upstream of Condon Creek.
- 1939 air photos were obtained from Oregon State University. The 1939 photos were taken by the Army Corps of Engineers, and only show the mainstem of the North Fork Siuslaw River from the mouth to the Portage.
- 1962, 1984 and 1994 air photos are archived at the Siuslaw National Forest Supervisor's Office.
- High elevation photos were flown in March 1996 to evaluate the effects of the February 1996 flood. These photos are archived at the Siuslaw National Forest Supervisor's Office.

The river channel's location and the extent of riparian vegetation (trees and brush) were traced onto drafting film (mylar). These mylar maps were reduced to the same scale as the 1994 map of the river, and the historic location of the river channel was overlain with the 1994 channel location. Historic channel locations were then digitized onto new layers (computer files) using ArcView™.

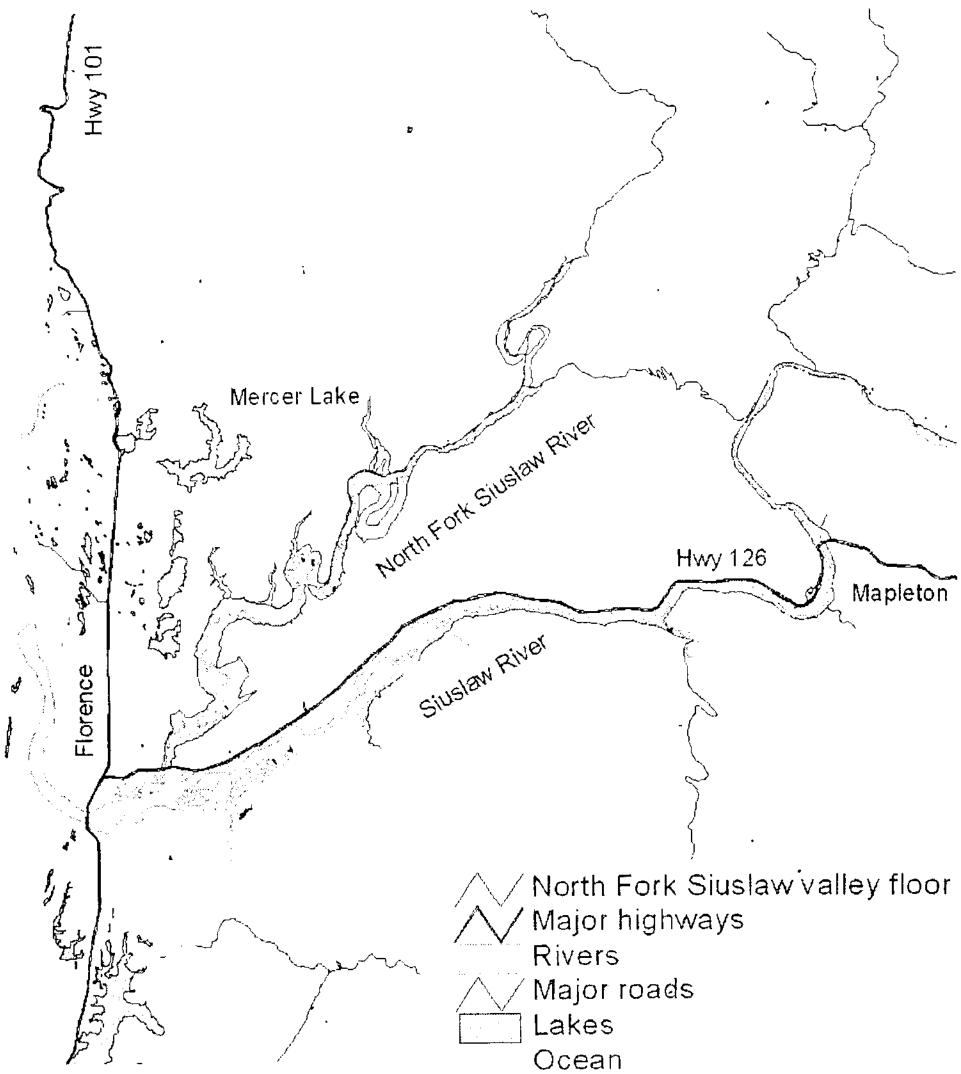

Figure 1: Location map of the North Fork Siuslaw River.

Cross-sections were measured at two locations just downstream from McLeod Creek using a laser level. These cross-sections were used to classify the North Fork Siuslaw River channel according to the system developed by Dave Rosgen (1996). Classifying the river according to Rosgen's system allows better evaluation of what restoration methods might be appropriate. The cross-sections and stream classification are covered in more detail in a later section of the report.

Geologic Setting of the North Fork Siuslaw River

The North Fork Siuslaw River watershed is underlain by the Tyee Formation, which consists of beds of siltstone and sandstone that were deposited in a large coastal plain and delta approximately 40 million years ago. A few scattered dikes of basalt are found in the watershed (Figure 2).

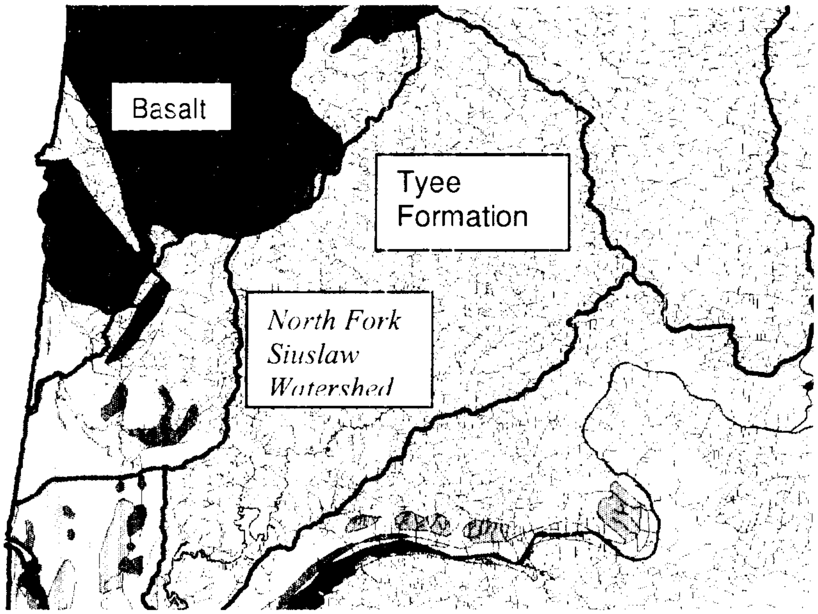

Figure 2: Geologic Map of the North Fork Siuslaw Watershed.

Approximately 25 million years ago, uplift of the Oregon Coast Range began, and the major rivers began to downcut through the Tyee Formation to form the present day river valleys. During the Pleistocene (2 million years to approximately 11,000 years ago), melting glaciers caused sea level to rise and drowned many of the river mouths in Oregon north of Bandon, forming bays and inlets. Sediment deposition along the lower portions of valleys has kept pace with rising sea levels, resulting in broad valleys suitable to human settlement (Orr, et al., 1992).

Landslides, in the form of both debris torrents and rotational slumps, are the primary mechanism for erosion in the Coast Range. Surface erosion on undisturbed areas is relatively uncommon, due to the dense vegetation cover and the high infiltration rates of the soil.

Sediment in low-gradient streams that flow through the Tyee Formation may consist of small gravel and sand. The sandstones and siltstones of the Tyee Formation are not well cemented and crumble easily, and tend to break down into small particles. The basalt is a much harder rock, and basalt cobbles and pebbles do not break down into smaller particles as easily.

Old, large meanders that are defined by the valley floor are present in the landscape upstream of McLeod Creek, at Fossback Marsh, and the Portage (Figure 3). Fossback Marsh is an abandoned meander. At some time in the past, the river cut a new channel across the meander. Abandoned meanders are not uncommon in the Oregon Coast Range. Similar abandoned meanders are found along the Yaquina River (Boone and Nute Sloughs) and along Five Rivers (Swamp Creek).

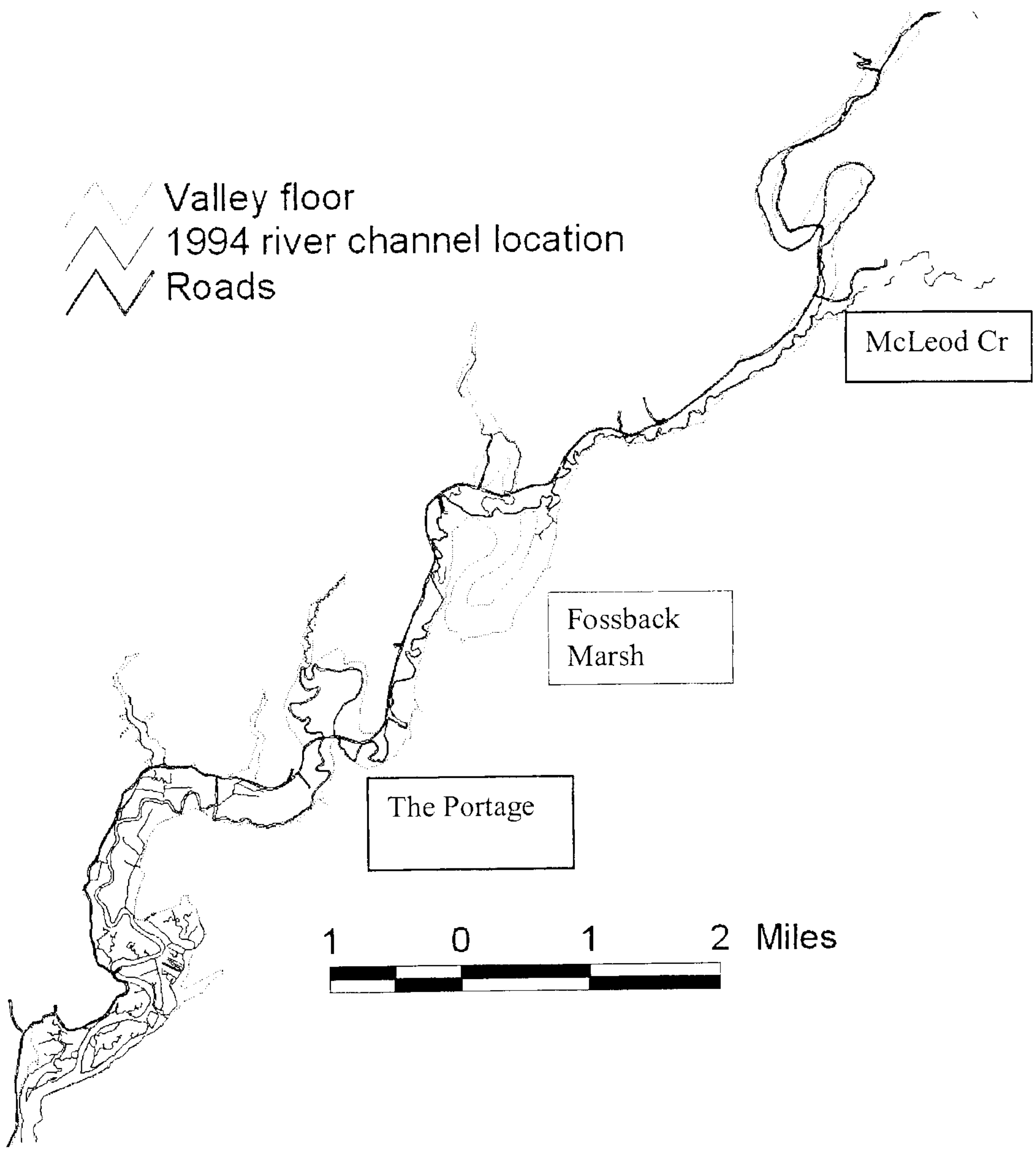

Figure 3: Large ancient meanders in the North Fork Siuslaw watershed. The large meanders in the valley floor are located north of McLeod Cr, at Fossback Marsh, and at the Portage. Fossback Marsh occupies an ancient meander that has been cut off from the mainstem of the North Fork Siuslaw River.

Recent History of the North Fork Siuslaw River

Information from Government Land Office (GLO) survey notes

Historic information from the Government Land Office (GLO) survey notes was provided by Charlie Dewberry, who gathered and analyzed the information. GLO surveys were conducted by walking section lines and noting the natural features and vegetation. These surveys were conducted in 1879 in the North Fork Siuslaw River valley, and provide insight into the condition of the river and local vegetation at that time.

The notes and the accompanying map (Figure 4) show that the river around the Portage, and just downstream (T18S, R11W, Sections 7 and 8) has not changed much since the surveys were done. Also, the notes show that the river channel was north of Fossback Marsh in 1879, and that the marsh had been cut off from the mainstem of the river by then.

Information on the amount and location of large wood in the river channel is sketchy. Because the survey was conducted by walking section lines, only the logjams that occurred on a traverse would have been noted and recorded. A large logjam was recorded below the Portage between river mile 5 and 6 (see Figure 4). The jam had buried one bank under wood, and was big enough for the surveyors to walk across. Other logjams and large wood were probably present in the river, but were not recorded in the survey notes. As with other streams and rivers in the Coast Range, there would have been periodic deposition of logjams, which would have captured gravels and helped to aggrade the river bottom. By 1880-1890, the river was open for navigation, which suggests that the logjams had been cleared from the river by that time (Charlie Dewberry, pers. comm.).

No reference to the height of the riverbanks is made in the GLO notes. The 1930 oblique aerial photo of the valley seem to show some incision of the river channel (Figure 5); however, when the downcutting may have occurred is unknown. Incision of the river channel into the valley floor may have increased since settlement and the removal of large wood from the channel, but the evidence is circumstantial: Settlers considered the head of tide to be the downstream side of the Portage. Today, there is an average of one foot of tidal fluctuation at the upstream bridge of the Portage, approximately 2.8 miles from farther upstream. The fact that the tidal influence seems to reach farther up the river channel than it did a century ago may indicate downcutting of the river channel (Charlie Dewberry, pers. comm.).

The GLO surveyors noted when they would descend from the valley slopes into what was referred to as "river bottom vegetation", which consisted of vine maple, alder, and some willow. None of the trees recorded were very big, most were three to four inches in diameter. Some bigleaf maples were scattered across the valley floor. There is no evidence from the GLO notes of large mature conifers on the valley floor. The conifers were only found on terraces above the active floodplain. Large conifers didn't grow well on the valley floor, because the whole valley up to McLeod Creek consisted of wet, marshy soils. The valley bottom would partially dry out in the summer, but was too wet for long periods of time in the winter to allow the conifer to grow (Charlie Dewberry, pers. comm.). Leitle Creek, which drains into Tachenich Lake, and has never been settled or cleared of vegetation, may serve as a present-day model of what the vegetation and valley bottom of the North Fork Siuslaw River may have looked like prior to homesteading.

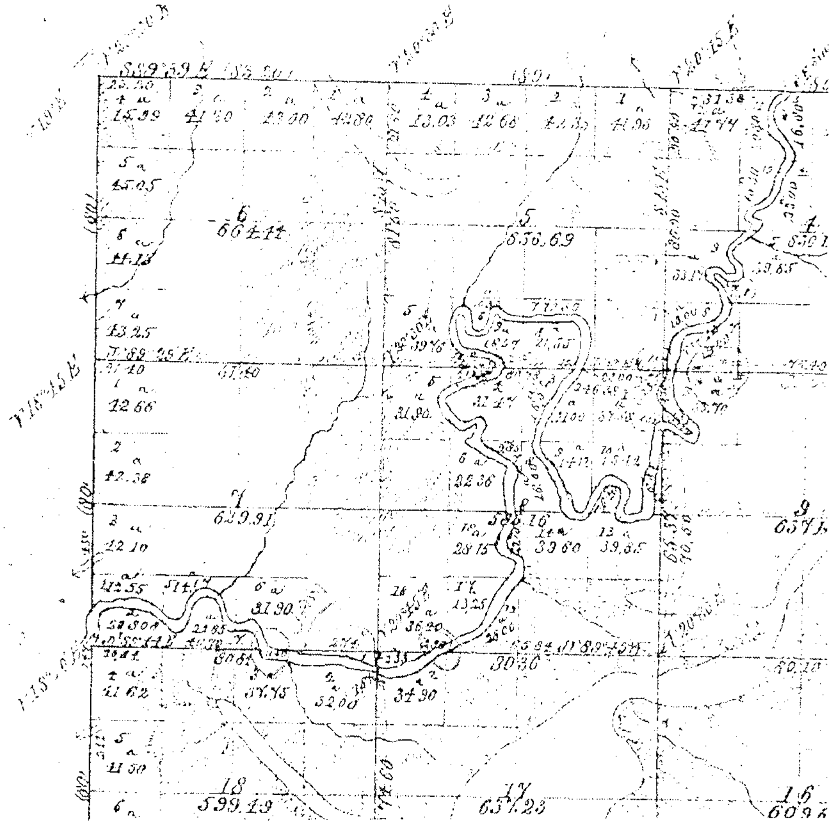

Figure 4a: 1879 GLO MAP

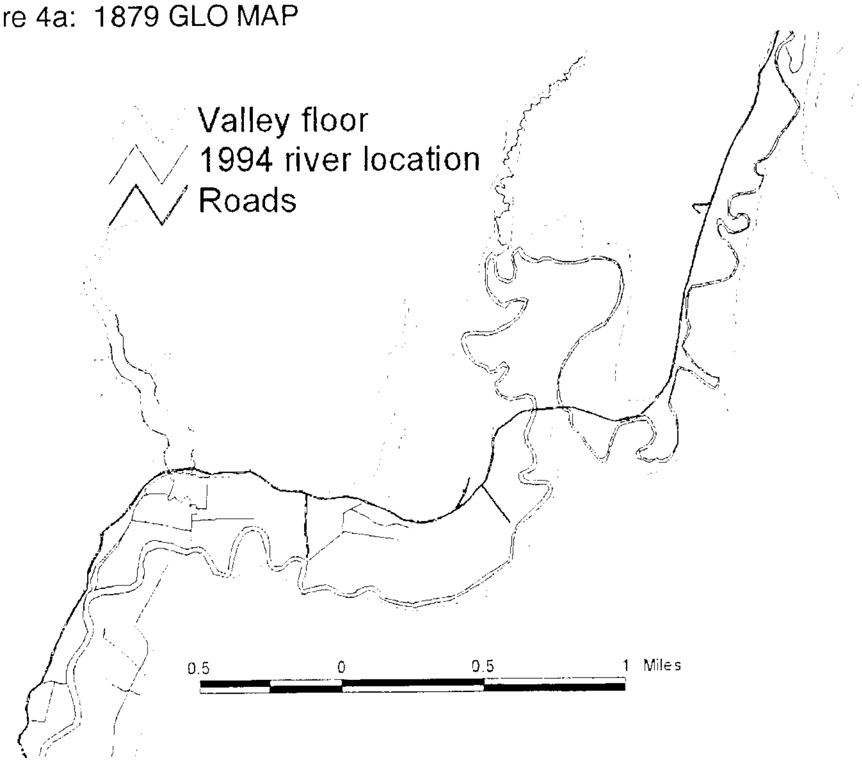

Figure 4b: 1994 map of North Fork Siuslaw River from aerial photography.

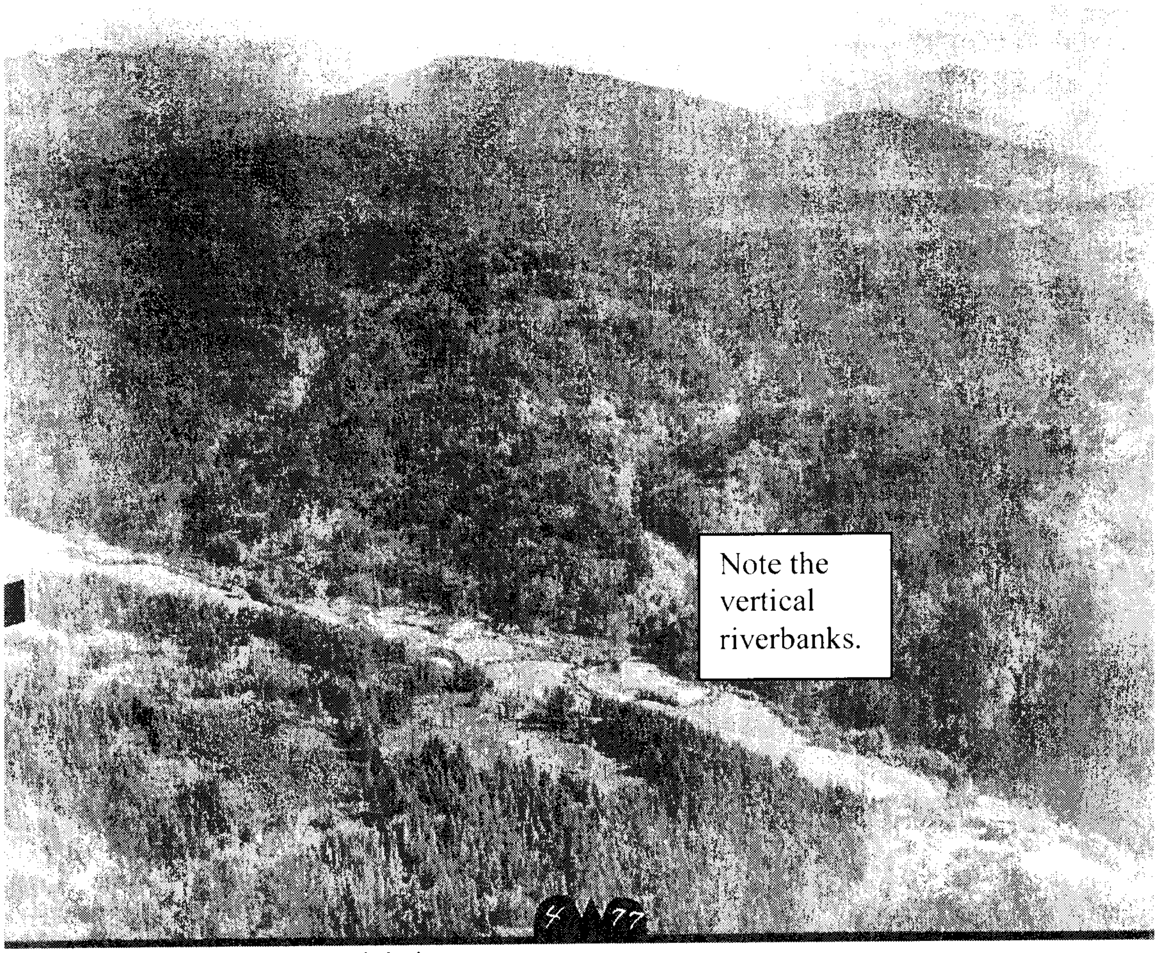

Figure 5: Oblique 1930 aerial photo.

<u>European Settlement of the North Fork Siuslaw River Valley</u>

The area south of the Alsea River, which had been part of the reservation set aside for the coastal Indian tribes, was opened to European-American settlement in 1875. By 1890, claims covered the valley bottom up to McLeod Creek, and by 1894, 39 ownerships had been established (North Fork Siuslaw Watershed Assessment, 1994).

One of the major effects of settlement on the North Fork Siuslaw valley was the removal of valley bottom vegetation. Reports by long-time residents confirm the information gleaned from the GLO notes. Bill Meadows remembers when the bottomland was all brush, and Norman Dick, Sr., remembered clearing 5 acres of land near the mouth of Condon Creek in 1923. They removed maple, elderberry, occasional second growth fir, and brush. About two thirds of the brush was salmonberry and crab apple with vine maple scattered through it.

By 1893, there were 4 or 5 large sawmills near the mouth of the North Fork Siuslaw River, and the river was used for log drives until 1955. A splash dam at Wilhelm Creek was used in the early 1920's to augment the flow of the river for log drives. The effects of the log drives on the river were not recorded; however, naturally occurring logjams would have hindered transportation, and were probably removed. The flow of large logs may also have gouged the river bottom and banks, resulting in a deeper channel.

In the lower tidal zone, the river was diked and tide gates were installed between 1910 and 1915. The dikes show up clearly in the 1939 air photos. As a result, the river channel in this area has been locked in place since that time.

Between 1952 and 1968, some of the tributaries, specifically Condon and Lindsey Creeks, were channelized into ditches along the sides of their respective valleys. The mainstem of the North Fork Siuslaw River was not channelized, however.

Drainage in Fossback Marsh was altered when a tunnel was dug through the ridge west of the marsh and a small, unnamed stream was routed through the tunnel to join the North Fork Siuslaw River. It is not known when the tunnel was constructed; however, its existence was noted in a 1992 stream survey. See figure 6 for the location of the tunnel.

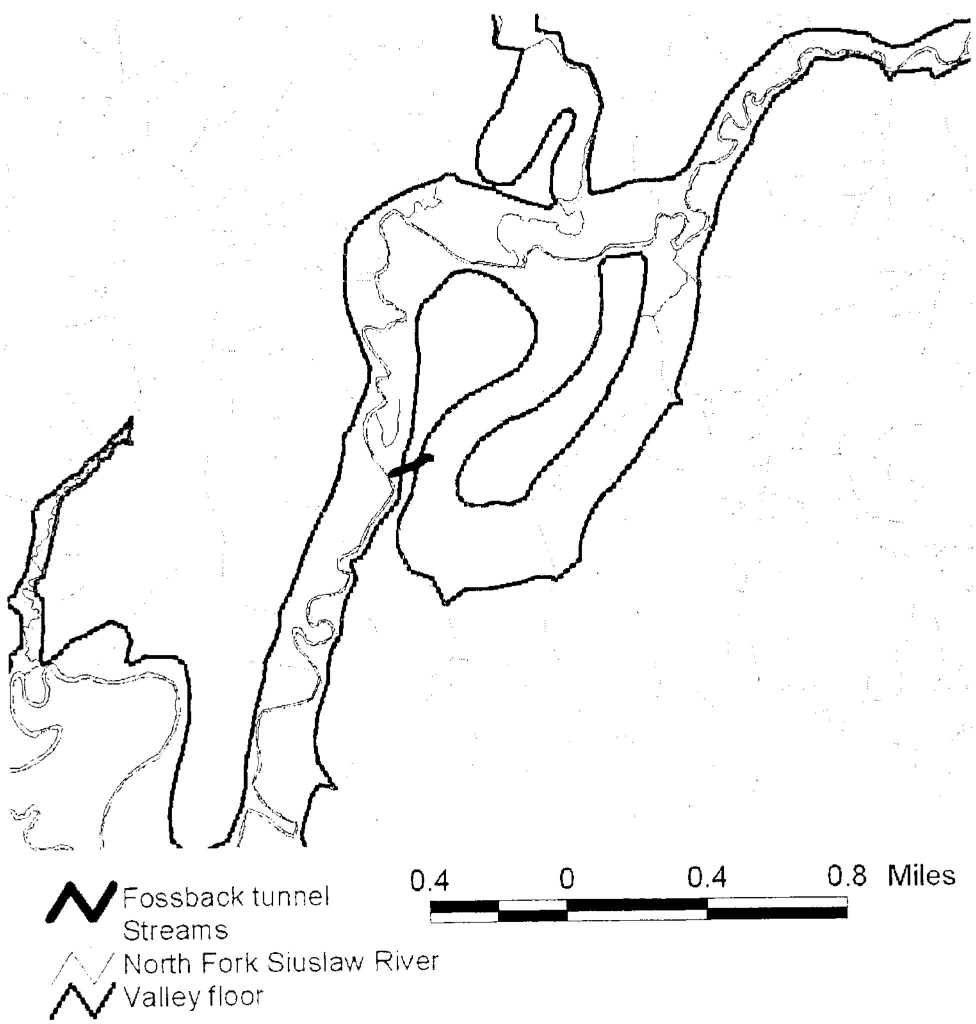

Figure 6: Location of tunnel cut through ridge to connect Fossback Marsh to the mainstem of the North Fork Siuslaw River.

Current Condition

Explanation of maps

The river location and riparian vegetation were mapped from each set of air photos. The riparian vegetation was mapped from the river's edge to 500 feet beyond the valley floor. On the side of the valley where the main road is located, riparian vegetation was only mapped between the river and the road. It was assumed that the road would prevent vegetation beyond the road from having an effect on the river. Three different symbols represent the riparian vegetation. Single dots were used to denote individual trees, a thick line was used to denote a strip of vegetation along the riverbank, and polygons were used to show where vegetation covered larger areas. See figures 7a, 7b and 7c, as well as Plate 1 for the vegetation mapping.

Assessment of Changes in Riparian Vegetation

The GLO survey notes imply that woody vegetation, mostly vine maple, alder and some willow, covered much of the valley bottom prior to homesteading. By the time aerial photographs were taken in the late 1930's, much of the valley bottom had been cleared and converted to farms and pastures. Only a thin, sometimes one tree wide, strip of brush and trees were left along the riverbank. This condition has remained much the same to the present day. Figures 7a, 7b, and 7c compare the 1930's vegetation coverage with the 1994 vegetation on a section of the North Fork Siuslaw River downstream from McLeod Creek. To see the entire study area, refer to *Plate 1: Comparison of Vegetation along the North Fork Siuslaw River between the years of 1937 and 1994.*

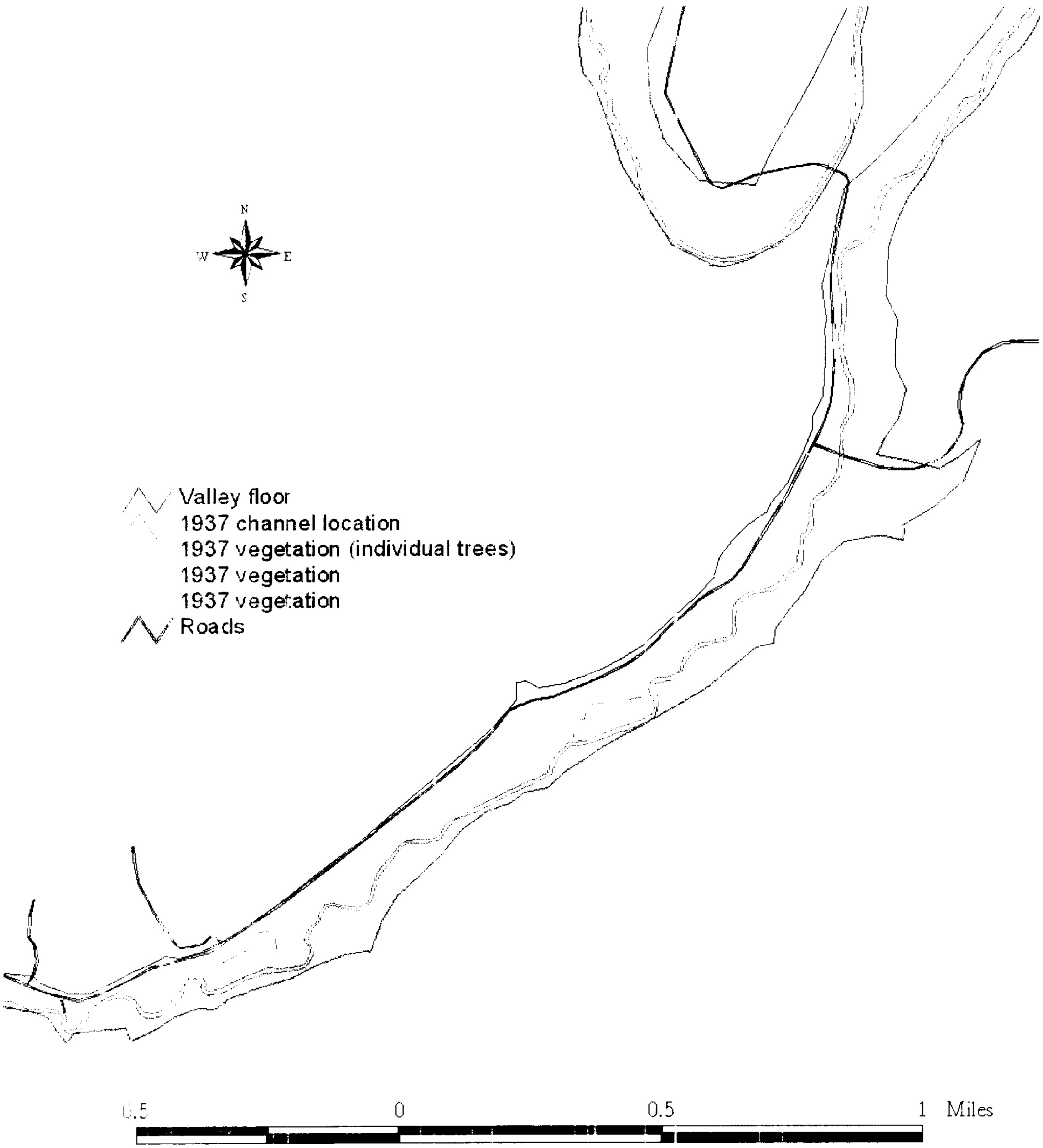

Figure 7a: Vegetation along the North Fork Siuslaw River in 1937. By 1937, much of the valley floor had been cleared of trees and brush.

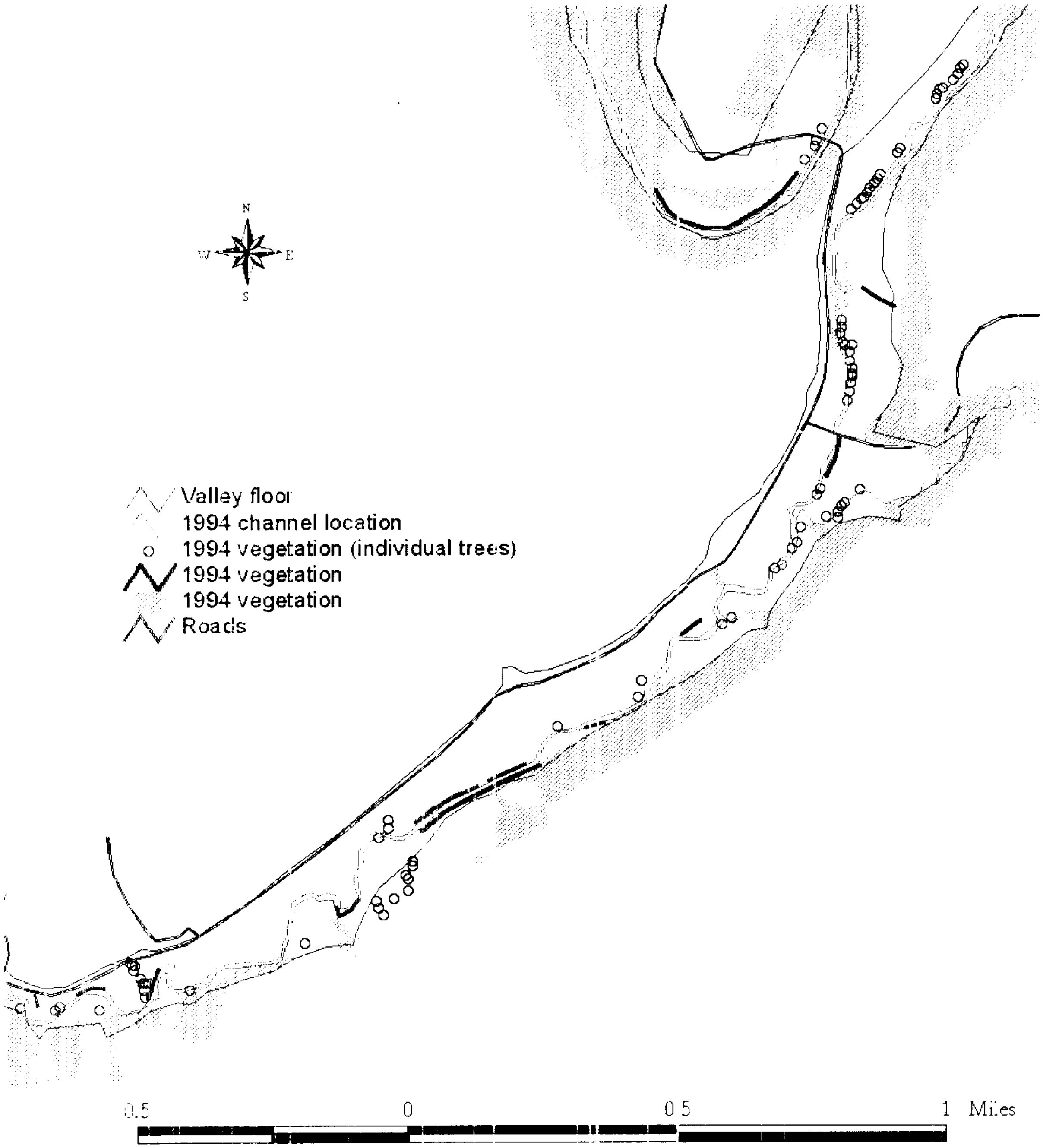

Figure 7b: Vegetation along the North Fork Siuslaw River in 1994.

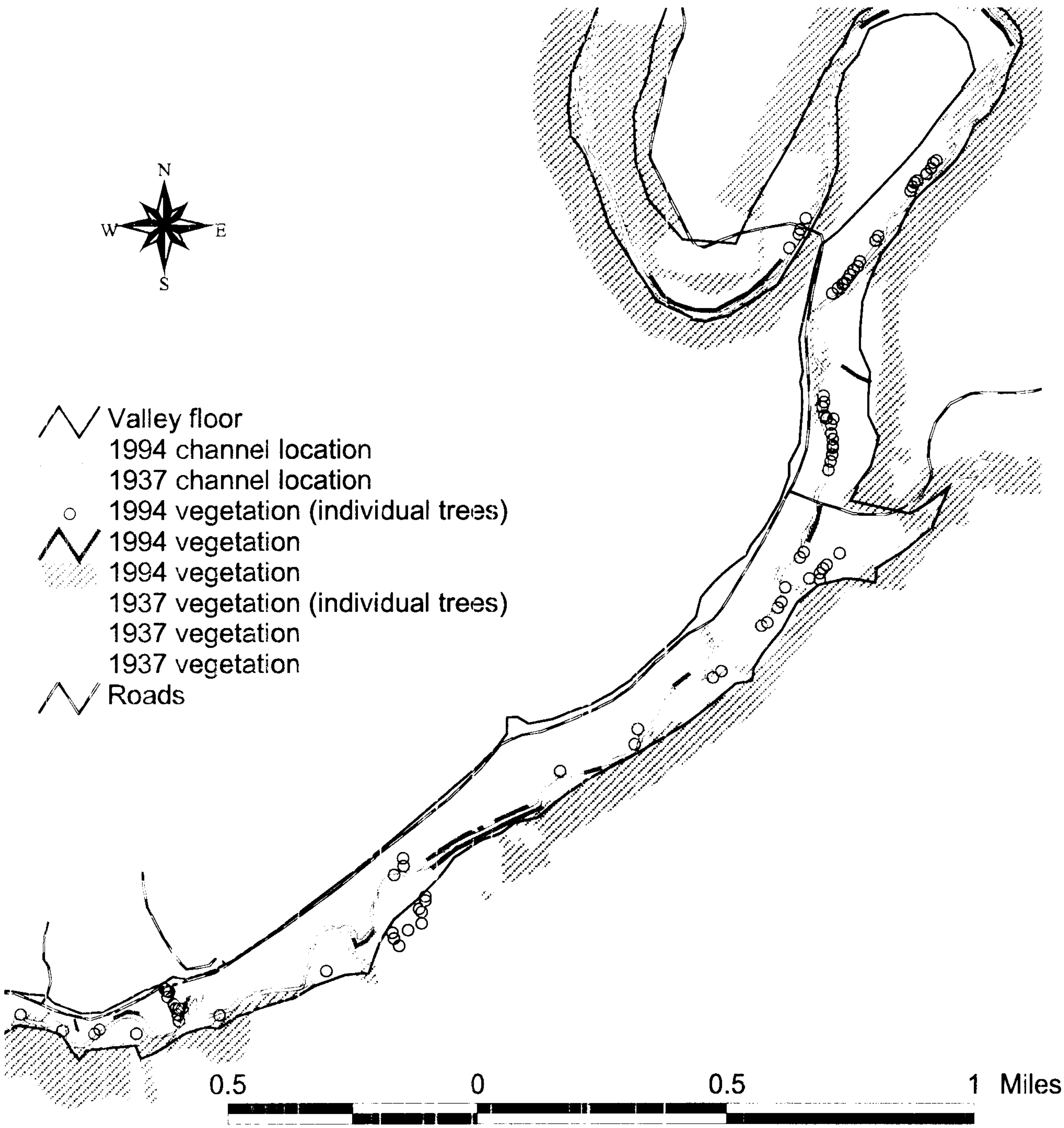

Figure 7c: Comparison of riparian vegetation in 1937 and 1994.

Assessment of Changes in Sinuosity

The sinuosity of the river was measured for the late 1930's and for 1994. Sinuosity is defined as the distance a river travels divided by the straight line distance between the same two points. The higher the number, the more sinuous the river. A straight channel (such as a ditch) would have a sinuosity equal to one. The river was divided into separate reaches, which are shown on figure 8. Point 1 was chosen as the starting point because the 1984 air photos did not cover the river farther south than that. Points 2, 3 and 4 were chosen because these locations have all been identified as the extent of tidal influence at various times. Points 5 and 6 were chosen to bracket the unusually straight reach in the North Fork Siuslaw River. Point 7 marks the location where the valley becomes narrow upstream, and the river gradient becomes steeper. Point 8 is the upstream limit of this study.

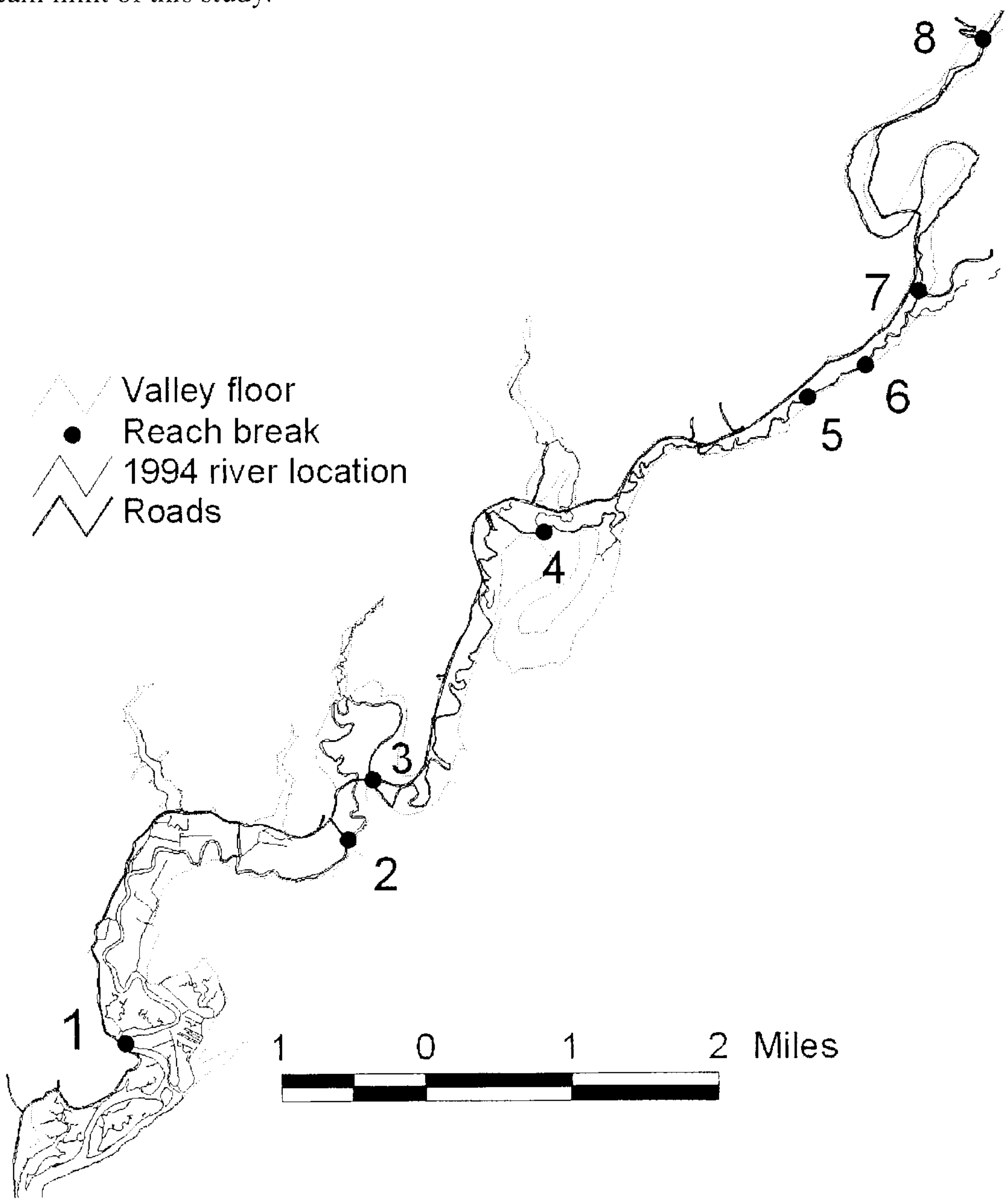

Figure 8: Map of reach breaks.

The reaches between points 1 and 3 are in the tidal influence zone, where the river was extensively diked between 1910 and 1915. The river reach between points 1 and 2 has the lowest gradient, and as expected, the highest sinuosity. The sinuosity between points

2 and 3, the river around the Portage, is quite low. The map from the 1879 GLO survey shows the river in the same location, so the unusually low sinuosity appears to be a natural feature. There is a gap in coverage between the 1937 and 1939 air photos between points 3 and 4, so the late 1930's sinuosity could not be measured. The reaches above point 4 show a very slight increase in sinuosity between 1937 and 1994. Above point 7, the valley becomes narrow and confined, and the sinuosity of the river reflects that. A comparison of the results is shown in Table 1.

Table 1: Sinuosity of North Fork Siuslaw River

Reach	1937 & 1939 River Length	1994 River Length	Valley Length	1937 Sinuosity	1994 Sinuosity
1-2	6581	6581	4125	*1.60*	*1.60*
2-3	4526	4526	2644	*1.1*	*1.1*
3-4	No data	6782	4332	*No data*	*1.57*
4-5	4639	4945	3244	*1.43*	*1.52*
5-6	754	754	727	*1.04*	*1.04*
6-7	1120	1160	991	*1.13*	*1.17*
7-8	6608	6637	6376	**1.04**	*1.04*
4-7		6859	4962	*1.31*	*1.38*

Assessment of Lateral Migration

Most of the bank erosion and lateral channel migration has taken place upstream from Condon Creek (point 4 on Figure 8) (see Plates 2 and 3, and Table 2). The river in the tidally influence lands has been diked since the 1910's (see Plate 2); and hasn't been allowed to migrate. The area just downstream from McLeod Creek has experienced the most lateral migration of the stream channel (Plate 3), possibly because of an influx of sediment, and deposition of sand and gravel bars just downstream from McLeod Creek. Slightly more stream length was affected by bank erosion and lateral migration between 1952 and 1962 in the reaches between points 4 and 5, and points 6 and 7 than in other years.

An unusually straight section of river channel exists between points 5 and 6 for a distance of almost half a mile (Plate 3). The straight section doesn't appear to be controlled by riprap or hard bedrock, and the banks are sandy (Johan Hogervorst, pers. comm.) In addition, no lateral migration appears to have taken place over the time period covered by aerial photography (1937 to the present). This straight segment of river channel is bracketed by channel segments that have been actively migrating and maintaining their sinuosity. The reason for this unusually straight and immobile segment is unclear, and puzzling.

Table 2: Length of stream with lateral migration by reach and time period

Reach	Length of channel with lateral migration between 1937-1952 (meters)	Percent of channel length with lateral migration, 1937-1952	Length of channel with lateral migration between 1952-1962 (meters)	Percent of channel length with lateral migration, 1952-1962	Length of channel with lateral migration between 1962-1984 (meters)	Percent of channel length with lateral migration, 1962-1984	Length of channel with lateral migration between 1984-1994 (meters)	Percent of channel length with lateral migration, 1962-1984
Point 3 to 4	1433	21.13	0	0	0	0	0	0
Point 4 to 5	2187	44.53	2241	45.32	1470	29.73	1184	23.94
Point 5 to 6	0	0	0	0	0	0	0	0
Point 6 to 7	1016	87	819	70.6	761	65.6	423	36.46
Point 7 to 8	776	11.69	223	3.36	1129	17.01	229	3.45

Stream Flow Data

The US Geological Survey stream gage, which was in operation from 1967 to 1985 was located just upstream from Condon Creek. The location of the stream gage is shown on Figure 9. Floods in the North Fork Siuslaw watershed occurred in 1964, 1972, 1984 and 1996. Peak stream flows in 1972 and 1984 reached 2280 cfs (cubic feet per second) and 3900 cfs respectively. Unfortunately, by 1996, the stream gage was no longer in operation. For comparison, the peak flow for the 1.25 year recurrence interval for the North Fork Siuslaw River is 2230 cfs.

Stream Temperature

Stream temperatures in the North Fork Siuslaw watershed have been monitored at various locations since 1994. Data from three sites on the mainstem of the river are shown in Table 3, and the locations are shown in Figure 9. The Department of Environmental Quality has set a standard of a 64F for the maximum temperature of the running 7-day average of the daily maximum. The North Fork Siuslaw meets this standard upstream from the PAWN trailhead, but summer temperatures exceed this standard downstream, probably due to a lack of shade, and the southwest orientation of the valley.

Table 3: 7-day average maximum temperature (in degrees F)*

Site	*Site Map Number*	*1994*	*1999*	*2000*
North Fork Siuslaw River upstream from PAWN trailhead	205	60.64	63.8	
North Fork Siuslaw River near campground	210	71.09	65.8	68.3
North Fork Siuslaw River upstream from Condon Creek	214	69.56		

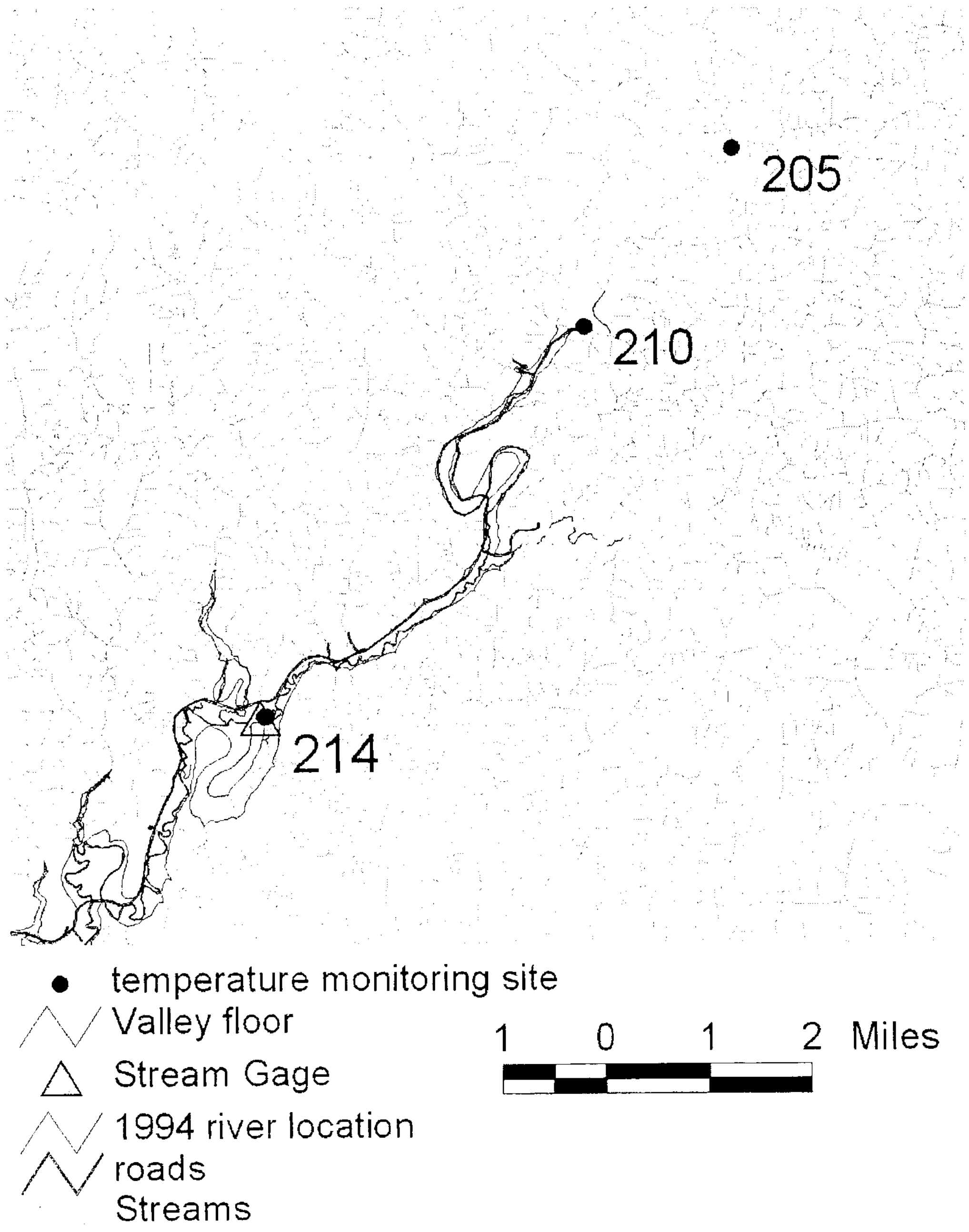

Figure 9: Location of U.S. Geological Survey stream gage and temperature monitoring sites on the North Fork Siuslaw River.

What kind of channel is the North Fork Siuslaw River?

Describing a river channel in the context of a classification system allows comparison to other rivers that have been studied, and some general conclusions can be made regarding the stability of the channel, how sensitive the river channel might be to disturbances in the watershed (for example, an increase in sediment load, or the loss of riparian vegetation), if and how the channel might adjust to changes that have occurred in the watershed and the stream channel, and what restoration techniques might be appropriate.

Dave Rosgen's (1996) stream classification system is used to describe the North Fork Siuslaw River. In his system, stream types are given a letter. "A" streams are steep headwater streams, "B" streams have a slope ranging from 2-4%, and "C" through "G" streams are low gradient (less than 2% slope) streams. Stream types "C" through "G" differ according to how deeply entrenched they are in the floodplain, sinuosity, and width/depth ratios. A number is assigned to describe the type of substrate. For example, a C4 stream has a sand and gravel substrate; a C5 stream has a sandy substrate.

Rosgen's (1996) system of classification is useful in restoration work because it can describe the current state of the channel, and suggest what restoration methods may be appropriate.

An abbreviated description of channel characteristics is found in tables 4 and 5. The C, E F and G channels are shown because they seemed the most likely candidates that describe the North Fork Siuslaw River.

Table 4: Rosgen's Stream Classification System, generalized

	"C" channel	"E" channel	"F" channel	"G" channel
Width/Depth Ratio	>12	<12	>12	<12
Entrenchment Ratio*	>2.2	>2.2	<1.4	<1.4
Sinuosity	>1.2	>1.5	>1.2	>1.2

*The entrenchment ratio is found using the following method: Find the maximum bankful depth on the cross-section. Double this depth. Project this elevation horizontally until it intersects the banks or sides of the valley. This elevation is called the floodprone width. Divide the floodprone width by the bankful width to find the entrenchment ratio.

Table 5: Rosgen's Stream Classification System with more detail

A. Stream Types with Gravel and Sand Substrate

	Value	C4 Channel	E4 Channel	F4 Channel	G4 Channel
Width/Depth Ratio	Low	13.5	2.0	12	3.9
	Average	29.3	5.86	28.22	8.21
	High	75	10.0	84	11.3
Entrenchment Ratio	Low	2.7	2.2	1.0	1.1
	Average	5.26	56.9	1.18	1.26
	High	10	1000	1.37	1.4
Sinuosity	Low	1.43	1.3	1.5	1.2
	Average	1.92	1.87	1.74	1.36
	High	2.8	2.6	2.0	1.55

B. Stream Types with Sand Dominated Substrate

	Value	C5 Channel	E5 Channel	F5 Channel	G5 Channel
Width/Depth Ratio	Low	12.6	2.0	11.9	2.5
	Average	27	5.78	21.3	7.18
	High	46.0	10.0	77	11
Entrenchment Ratio	Low	2.25	2.27	1.05	1.1
	Average	2.96	39.5	1.14	1.17
	High	4.0	200	1.3	1.33
Sinuosity	Low	2.9	1.2	1.4	1.2
	Average	3.45	2.35	1.43	1.25
	High	4.0	3.4	1.45	1.3

Brief Decription of Channel Types

"C" channel

The C channel is a low gradient, meandering stream that is relatively wide and shallow. It is only slightly downcut into the floodplain, and the banks are not very high. The floodplain is well-developed It actively moves across the floodplain by eroding banks and depositing bars on the inside of meander bends. Rates of migration are influenced by the presence and type of riparian vegetation. The "C" type of channel is sensitive to disturbances, such as increased sediment load, or removal of riparian vegetation. (Rosgen, 1996)

"E" channel

The "E" stream types are low gradient streams with high sinuosity. They are narrow and deep compared to the "C" channel. The stream banks tend to be vertical, but are stable because of the dense vegetation that is usually found along this stream. The "E5" channels are very stable unless the stream banks are disturbed and significant changes in sediment supply and/or stream flow occur. (Rosgen, 1996) The "E" type streams are typically found in wetland or marshy environments.

"F" channel

The "F" stream type is a low gradient, meandering channel that is deeply downcut into the floodplain. The "top of banks" elevation for this stream type is much greater than the bankful stage , which is indicative of the deep entrenchment. The "F" channel is like a "C" channel that has downcut into the floodplain. The "F" channels are wide and shallow. Depositional features are common in this stream type, and over time tend to promote development of a floodplain inside of the bankful channel. Stream bank erosion rates are very high, which enhance the deposition of sediment in the stream from eroded bank materials (Rosgen, 1996).

"G" channel

The "G" stream type is a low gradient stream that is either deeply downcut into the floodplain, or in the process of downcutting. Like the "F" channel, it has high stream banks, high rates of bank erosion, and is usually the result of a "C" channel that has downcut into the floodplain. It differs from an "F" channel because the sinuosity is lower, and it isn't as wide and shallow. It is very sensitive to disturbance in the watershed (Rosgen, 1996).

Discussion of the Cross-Sections on the North Fork Siuslaw River

Cross-sections were measured downstream from McLeod Creek, and were used to classify the river channel according to Rosgen's (1996) methodology. The location of the cross-sections is shown in figure 10, and the cross-sections is shown on figure 11. Numerical data derived from the cross-sections is shown in Table 6.

Table 6: Measurements from Cross-Sections of the North Fork Siuslaw River

	Cross Section 1	**Cross Section 2 Active channel**
Bankful width	51	53 ft
Mean Depth	4.35	5.0 ft
Maximum Depth	5.9	6 ft
Substrate	Gravel and Sand	Sand
Floodprone Width	*Infinity*	*92 ft*
Width/Depth Ratio	*11.72*	*10.55*
Entrenchment Ratio	*Infinity*	*1.73*
Sinuosity	*1.52*	*1.04*

The North Fork Siuslaw does not fit neatly into any one stream type. This lack of correlation suggests the stream channel may be evolving from one stream type to another. Cross-section 2 measures an abandoned channel (not shown), as well as the active channel. Assuming the abandoned channel has not been modified or filled in, the bottom of the channel is approximately 5-6 feet below the valley floor. The active channel, on the other hand, is downcut approximately 16-18 feet below the valley floor. Comparing the depths of the two channels suggests considerable downcutting into the floodplain has taken place. Based on the numerical data from the cross-sections, and the qualitative

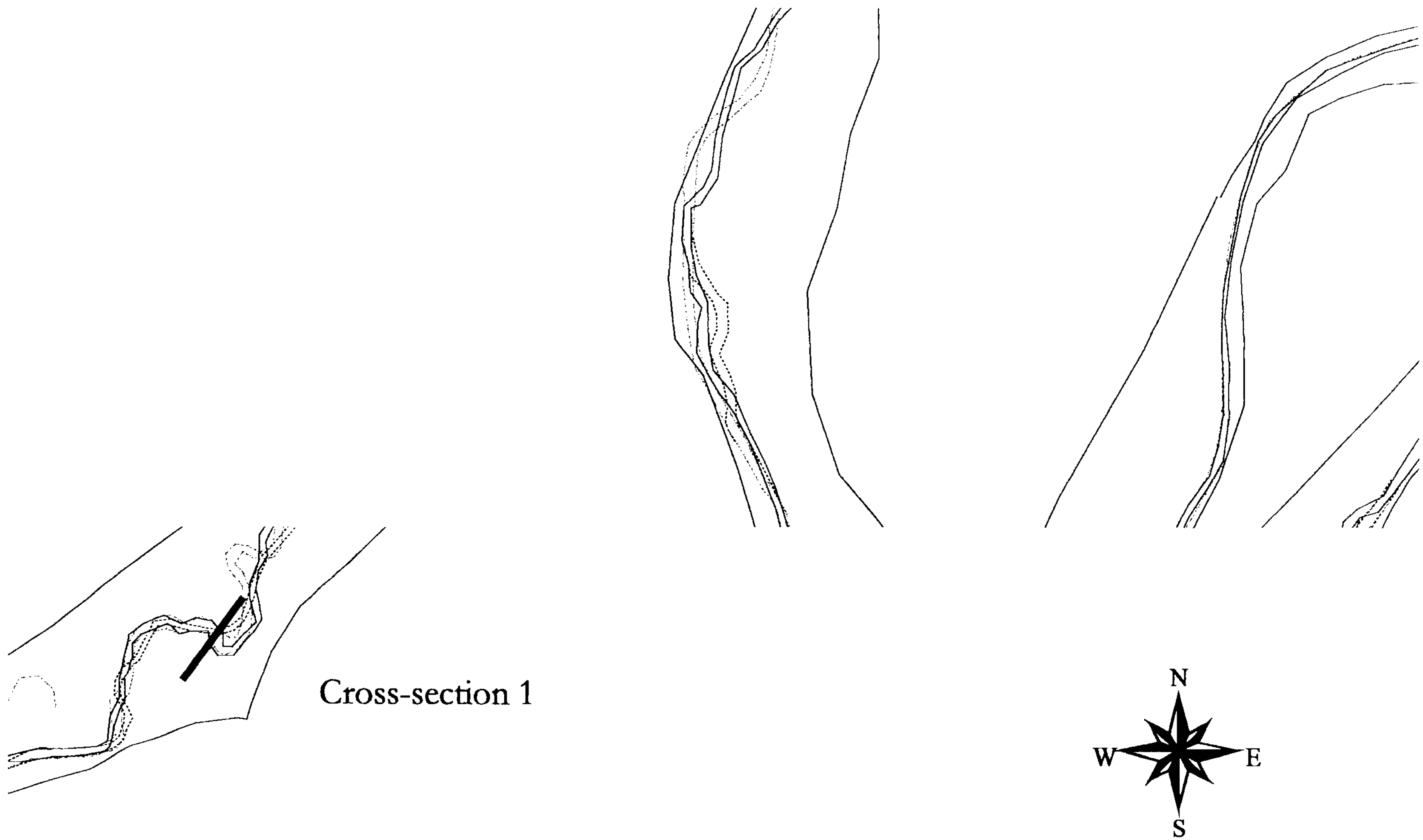

Figure 10: Location of cross-sections on the North Fork Siuslaw River.

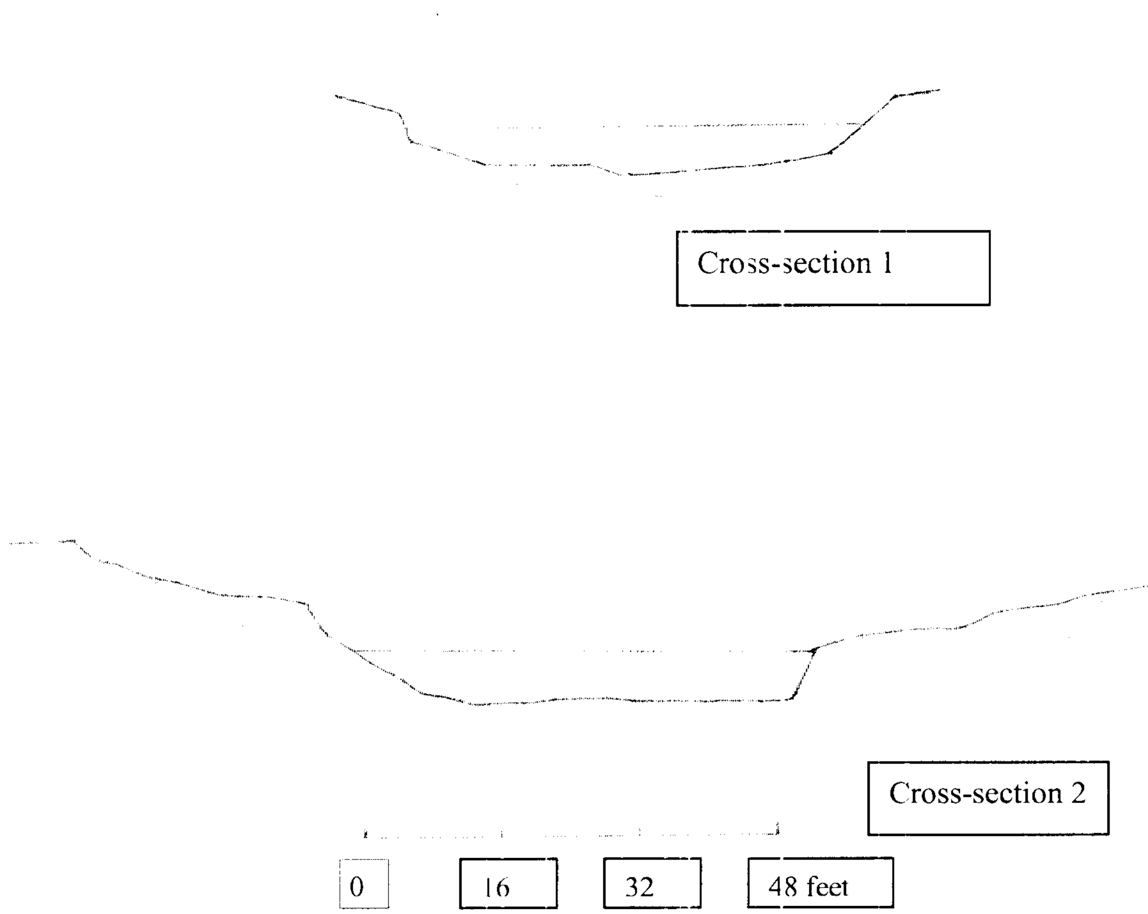

Figure 11: Cross-sections on the North Fork Siuslaw River.

descriptions of the channel types, the North Fork Siuslaw River seems to be between a "C5" and an "F5" channel. For example, the entrenchment ratio of 1.73 is between the values given for a "C" channel and an "F" channel. The cross-section data, including comparing the abandoned channel with the active channel, suggest the North Fork Siuslaw may have started as a "C" channel, then evolved into an "F" channel as it downcut into its floodplain. It may be starting to revert back to a "C" channel at a lower base level.

The reason(s) for the apparent downcutting are not clear, but the history of the North Fork Siuslaw watershed suggests clues. Removing the large wood to aid navigation and log transportation would have eliminated natural grade control structures that would have held back the bedload of sand and gravel. Once the grade control structures (log jams) were gone, the river would have been able to downcut into the bed of accumulated sands and gravels. The log drives themselves would have gouged the riverbed and banks, and possibly deepened the river channel. Loss of riparian vegetation may have contributed to the downcutting. Many of the large trees that could have fallen into the channel, held back gravels, and added complexity to the channel morphology as the river flowed around them would no longer have been available.

The pre-settlement meander cut-off at Fossback Marsh may have been another contributing factor to the downcutting in the river channel. When the river abandoned the large meander through Fossback Marsh, the length of the channel was shortened by 17,500 feet (assuming a sinuosity of 1.5) (Figure 12). As a result, the gradient across the

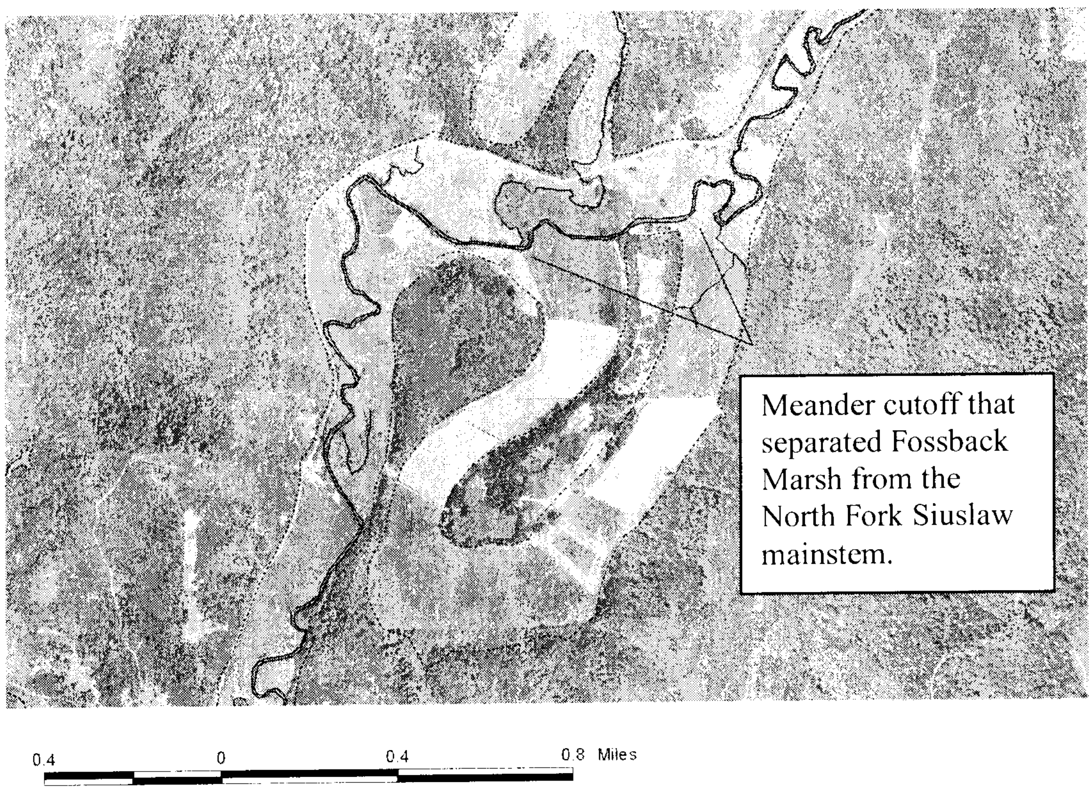

Figure 12: The abandoned meander at Fossback Marsh

meander cut-off increased. Assuming the original gradient was 0.03%, the gradient could have increased to 0.13%. The increased gradient in a local area could have caused a step in the gradient profile of the river. Removing the woody debris from the river could have removed a grade control, and allowed the headcutting to propagate upstream.

In conclusion, the amount and timing of the downcutting on the North Fork Siuslaw River is difficult to identify from the existing data. It probably has multiple causes, both natural and human-induced.

Assuming the river is downcut, what is likely to happen in the future? Both Schumm (1986) and Rosgen (1994) have developed a model for channel evolution for downcut streams (Figure 13). The model starts with a stream that is stable (Figure 13a); in other words, it could be migrating laterally, but the channel dimensions are staying about the same. Something happens to disturb the system, such as channel straightening, or removing grade controls, like large wood. The channel responds to the changes by downcutting into the floodplain (Figure 13b). After downcutting to a new base level, the stream begins to meander and the oversteepened banks are eroded. The stream channel becomes wider (Figure 13c). As the channel reaches a new equilibrium at the lower base level, it develops a new floodplain, and the old floodplain becomes an abandoned terrace (Figure 13d).

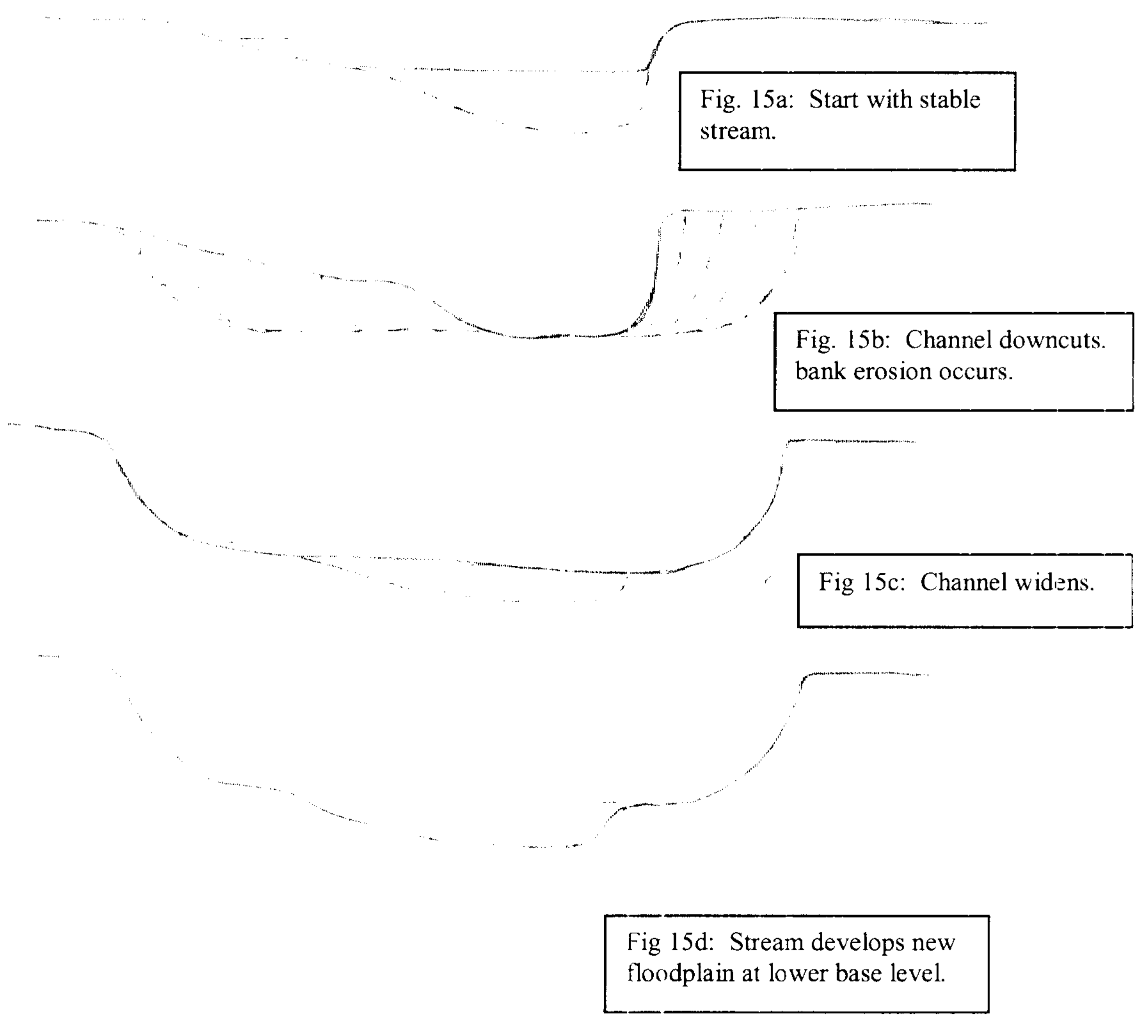

Figure 13: An example of channel evolution for a downcut stream.

What can be done to enhance (restore) the river?

General thoughts on stream restoration

A holistic approach to restoration that takes the entire length of the river into consideration is preferable to planning projects in a piecemeal, site-by-site manner. Each site should be considered in the context of the reach scale, and each reach should be considered in the context of the entire river. Projects should be evaluated for potential effects on the stream and streambanks both upstream and downstream from the site.

Bank erosion is a natural, healthy process in streams. Even undisturbed streams have bank erosion at the outside of meander bends and deposition of sediment on the inside of the bends. The most diverse habitat is found at the water's edge. Undercut banks, side channels, overhanging vegetation, and fallen trees provide essential habitat for fish, insects and wildlife. In healthy riparian areas, bank erosion introduces fallen trees and sediment into the river. It may result in side channels as the river moves back and forth across the floodplain.

Using riprap to slow or stop bank erosion has good and bad points. Riprap may be necessary to protect certain structures, such as bridge footings; or structures that are being threatened by accelerated bank erosion. However, for general bank protection and habitat restoration, it has drawbacks. Riprap is a hard, reflective surface, so water "bounces" off of the bank. None of the water's energy is absorbed. Willows and other vegetation tend to absorb the energy of the water near the bank, so water velocities are slowed. An analogy would be bouncing a ball on a hard, concrete surface compared to bouncing a ball on a mattress. Water velocities near banks with riprap can be 3 to 4 times as fast as banks with vegetation (see Table 7, and Appendix A),. As a result, there may be higher velocities, and more erosion, downsream of a site with riprap compared to a site with vegetation on the banks.

Table 7: Comparison of bank materials and mean velocities

Bank material	**Mean velocity near the bank**
Riprap	0.78 ft/sec
Willows	0.31 ft/sec
Weeds	0.22 ft/sec
Dense brush	0.18 ft/sec

Developing a restoration plan

There are a number of steps in developing a restoration plan. A suggested outline is given below:

1. Identify the problems, not just the symptoms. Knowing what caused the problem helps identify the best solution. The cause of a local problem may be off-site, for example, an increased sediment load from upstream, or headcutting and deepening of the channel that started downstream and is working its way up the

channel. Also, the causes may be large-scale and require a watershed-level approach; for example, working to treat areas with increased erosion.

2. What type of stream is this particular river or stream? Stream classification systems can help with this step. The restoration plan needs to take into consideration the current condition of the river, as well as the future trends. The restoration plan needs to accommodate the tendencies of the river and work with them. It also needs to recognize that recreating the historic conditions may not be possible, given changes that may have occurred in a watershed.

3. Identify the goals and objectives of restoration. There are usually multiple goals, such as better fish habitat, lower water temperatures, slower rates of bank erosion, etc. The goals and objectives will be one of the guides in the selection of restoration techniques.

4. Identify what is practical, and the possible constraints and issues. What will work with the time, money, equipment and labor available? What will be compatible with local land use?

5. Identify and plan the desired restoration techniques and designs. What species can be planted, and where? Are permits needed? If so, who will apply for them? How will funding be obtained? Who will do the work, volunteers or paid labor?

6. Maintenance. The restoration plan should include maintenance, if needed. For example, trees planted in a riparian area may need to be protected from beavers and rodents, and brush cleared on a yearly basis until they are big enough to survive on their own.

7. Monitoring: It is important to monitor a project to see if it is working as intended, and to learn what is effective. Knowledge gained through monitoring can be applied to future projects.

<u>Recommendations for the North Fork Siuslaw River</u>

Two issues that could be addressed in a restoration plan are bank instability and high water temperatures. Planting a wide buffer along the river with large trees, perhaps a mixture of conifer and alder would provide future shade and large woody material recruitment. Areas that flood on a yearly basis may not be appropriate sites for some conifer species, such as Douglas fir, and those areas should be planted with trees that are tolerant of wet or poorly drained soil conditions. Willows could be planted along the banks near the water's edge to slow the bank erosion, and enhance habitat.

Since the river appears to be downcut into unconsolidated sediments, caution should be used in putting log structures into the channel until the banks have more large vegetation growing on them. As long as the banks are unvegetated, the river might cut around the log structures and create more bank erosion. From the viewpoint of the river and the fish, this situation might not be a bad thing—it would add to the sinuosity and complexity of the channel. However, landowners may or may not want to have accelerated bank erosion.

Acknowledgements

Thanks to Charlie Dewberry for sharing his information and knowledge of the Government Land Office survey notes from 1879. Thanks also to Johan Hogervorst for measuring the cross-sections on the North Fork Siuslaw River.

References

Charlie Dewberry, personnal communication

Orr, E.L., Orr, W.M., and Baldwin, E.M., 1992, Geology of Oregon, 4th edition, Kendall/Hunt Publishing o., Dubuque, Iowa, 254 p.

Rosgen, Dave, 1996, Applied River Morphology, Wildland Hydrology, 1481 Stevens Lake Road, Pagosa Springs, Colorado.

Schumm, S.A., Watson, C., and Harvey, M., 1986, Incised channels. Water Resources Publications, Littleton, CO.

Appendix A: Flow Resistance and Manning's Equation

Manning's Equation is a commonly used equation in hydrology. It's used to calculate water velocities.

Manning's Equation: $U = \frac{1.49\ (R)^{2/3}(S)^{1/2}}{N}$

U = mean velocity
R = hydraulic radius (cross-section area/wetted perimeter)
S = slope
N = Manning's "n" (roughness coefficient)

For riprap, N = 0.023 to 0.033
For willows, N = 0.06 to 0.08
For weeds, N = 0.08 to 0.12
For dense brush, N = 0.10 to 0.14

Example: For simplicity, assume a rectangular channel that is 30 feet wide, and 2 feet deep, with a slope of 0.01%.
R = 60/34 = 1.7647
S = .0001

For riprap:

$$U = \frac{1.49\ (1.7647)^{2/3}(0.0001)^{1/2}}{0.028}$$

U = 0.7769 feet per second

For willows, N = 0.06 to 0.08

$$U = \frac{1.49\ (1.7647)^{2/3}(0.0001)^{1/2}}{0.07}$$

U= 0.31 feet per second

Bank material	**Manning's "N"**	**Mean velocity near the bank**
Riprap	0.023 to 0.033	0.78 ft/sec
Willows	0.06 to 0.08	0.31 ft/sec
Weeds	0.08 to 0.12	0.22 ft/sec
Dense brush	0.10 to 0.14	0.18 ft/sec

Conclusion: The type of material on the streambank influences downstream velocities, and the erosive potential of the stream. Riprap is a hard reflective surface, and the water tends to "bounce" off of it. Willows and brush, on the other hand, tend to absorb the power of the flowing water, and downstream velocities are half, or less, of the vecolities near banks with riprap.