REVIEW DRAFT

GEOMORPHIC AND RIPARIAN ASSESSMENT OF THE LOWER SOUTH FORK OF THE COQUILLE RIVER

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1. INTRODUCTION

The Coquille Watershed Association (CWA) is a locally organized, watershed-based group that works collaboratively with private landowners to identify, prioritize, and implement projects intended to restore upland, lowland, and aquatic habitat conditions within the Coquille River system. A primary area of interest and restoration effort for the group since it organized in the early 1990s has been the lower watershed of the South Fork of the Coquille River, a highly altered landscape of mixed ownership and degraded aquatic habitat. Projects the CWA has implemented to improve riparian conditions and stabilize streambanks along the lower mainstem of the South Fork and some of its tributaries have met with mixed success. Some projects the group has completed along the lower mainstem were significantly less successful than hoped, in large part because the river is large, powerful, deeply incised, and in some disturbed areas prone to bank erosion on a scale that can dwarf small-scale restoration efforts.

In early 2001, the CWA contracted Clearwater BioStudies, Inc. to conduct an assessment of riparian shade and geomorphic conditions along the lower South Fork and three of its tributaries as part of a larger analysis of stream shading and temperatures that covered several additional drainage networks within the Coquille system. The lower South Fork was included in the effort because it was (and is) on the Oregon Department of Environmental Quality’s 303(d) list of temperature impaired waterbodies. One of the three tributaries to be included in our work (Dement Creek) was (and is) similarly listed.

The following report describes the methods and results of our contracted assessment of the lower South Fork and the three tributaries of interest to the CWA: Dement Creek, Yellow Creek, and Hayes Creek. The assessment had two primary components, a geomorphic evaluation and an analysis of riparian shade conditions along the lower mainstem and the perennial channels within the watersheds of each of the three tributary watersheds. Both components were intended to help the watershed group better understand opportunities for riparian restoration that are available within the lower South Fork watershed. Per instructions from the CWA, the geomorphic evaluation followed hierarchical assessment procedures developed by Dave Rosgen (1996), with greater attention paid to the mainstem due to the group’s past experiences there and concerns about geomorphic influences on the potential for riparian restoration along the river. Our analyses of riparian shading along the streams and river were structured around SHADOW (USFS 1993), a computer spreadsheet model favored by the watershed group.

2. STUDY AREA

The study area included the 34.7 miles long "lower" South Fork and its riparian corridor from the Siskiyou National Forest boundary near Powers down to its mouth near Myrtle Point, Oregon, plus the perennial drainage networks and associated riparian corridors of the Dement, Yellow, and Hayes Creek watersheds (Figure 1). Collectively, these streams provide important but impaired habitat for multiple species of anadromous and resident fish. Riparian systems have been altered throughout the area, and a comprehensive review of the systems in the best condition, those on Bureau of Land Management lands, have been classified as not properly functioning with regard to eight of nine federal conservation objectives and at-risk with respect to the ninth. An earlier study of bank stability problems along the lower South Fork, and approaches to their solution, was conducted by Florsheim and Williams (1996) back in 1995, prior to a large flood in 1996 that had a recurrence interval of between 50 and 100 years.

The South Fork drains a watershed of greater than 550 mi^2 that includes areas within both the Coast Range and Klamath Mountains of southern Oregon. Natural processes and historic landuse practices have influenced the geomorphic characteristics of the watershed and bank erosion is currently a well-recognized problem along mid- and lower gradient reaches of the river system. The lower South Fork itself, below the National Forest boundary, is comprised of a series of responsive river reaches with channel gradients that decline from low (<1%) to exceptionally low (<0.1%) with increasing proximity to the mouth (Figure 2). The low gradients combine with the river's position within a substantially altered landscape to create a high potential for unwanted cumulative watershed effects.

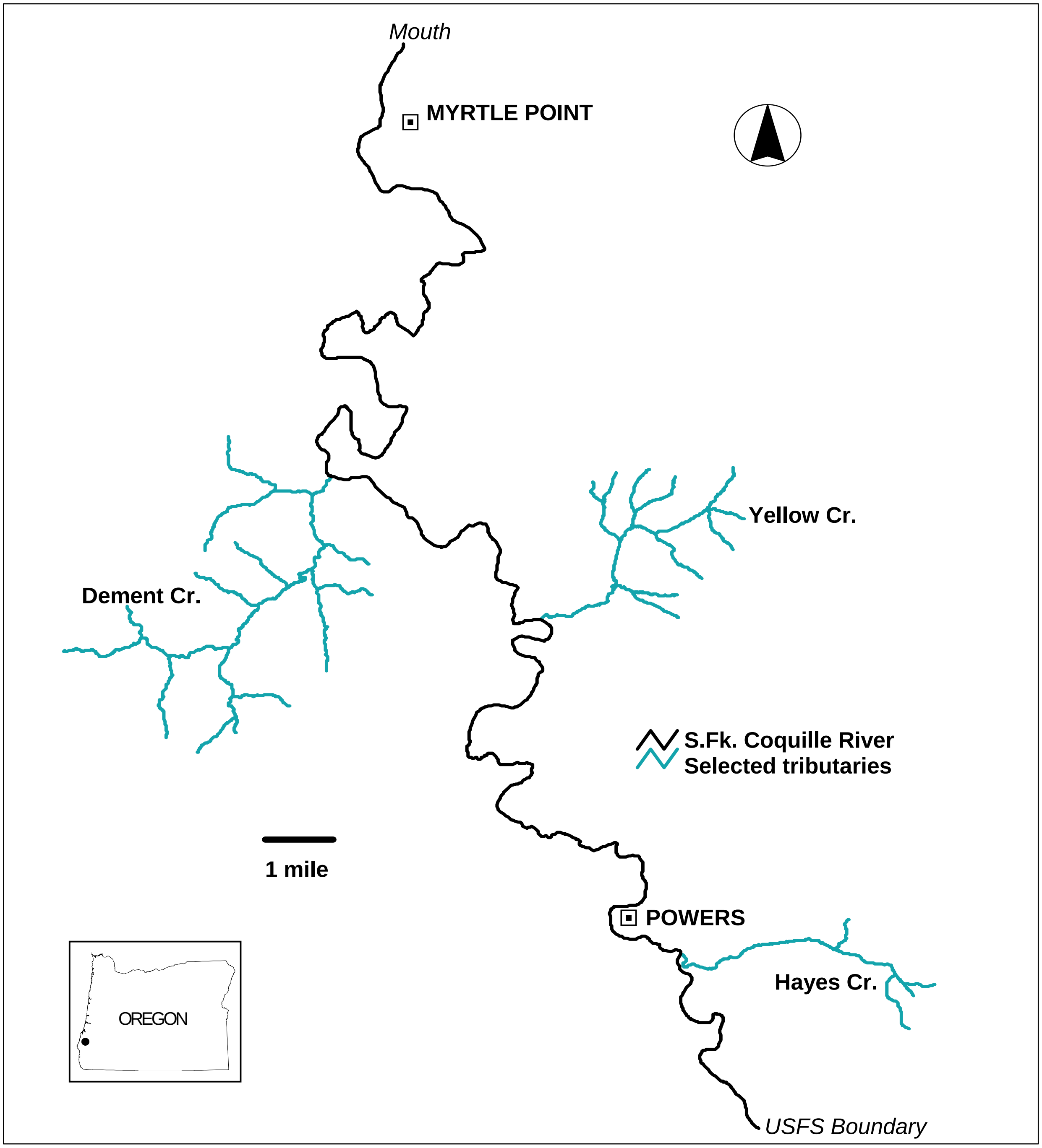

Figure 1. Location map for the lower South Fork Coquille River study area, including the mainstem river, Dement Cr., Yellow Cr., and Hayes Cr., Oregon.

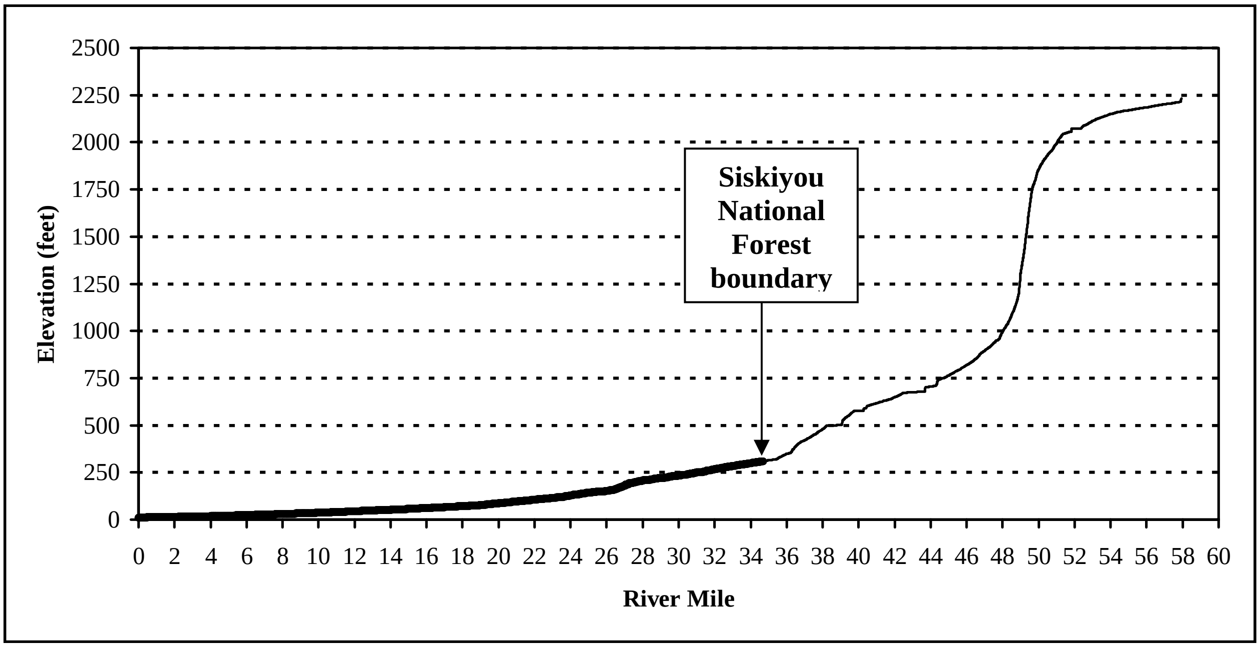

***Figure 2.** Longitudinal profile of the South Fork Coquille River, Oregon. The lower South Fork, below the National Forest boundary, is shown as a bold line.*

3. GEOMORPHIC ASSESSMENT

Stream channel conditions within the study area were assessed using methods described by Rosgen (1996), with an emphasis on the mainstem South Fork due to CWA concerns about severe bank erosion that has occurred along some segments of the lower river in recent years. Our evaluation of the mainstem included what are commonly referred to as Level I, Level II, and Level III Rosgen analyses. These hierarchical analyses were conducted to help define existing conditions along the lower river and to provide a geomorphic context for future restoration efforts. Geomorphic evaluations of streams within the Dement Cr., Yellow Cr., and Hays Cr. watersheds were limited primarily to a Rosgen Level I analysis intended to characterize existing channel conditions within these three watersheds in a very general way.

3.1. LEVEL I -- GEOMORPHIC CHARACTERIZATION

We conducted a Level I Rosgen analysis that relied largely on 1:12000-scale color air photos taken in 1997 and 7.5-minute USGS topographic maps to break the stream network up into general “types” of channel segments or reaches that had distinctive geomorphic characteristics. The general stream types and their diagnostic characteristics are summarized in Table 1. Stream types “Aa” and “A” had deeply entrenched channels that were steep, had low sinuosity, and had low width/depth ratios. "B" stream types had moderate entrenchment, moderate width/depth ratios, moderate sinuosity, and typically had moderate channel gradients. Types "C" and "F" both had low gradient, meandering channels but were differentiated on the basis of whether the stream was well-connected to an extended floodplain. C-type streams had well-developed floodplains that they appeared likely to access during extreme high flows (low entrenchment), while F-types were deeply incised within the surrounding valley and appeared unlikely to access floodplains (high entrenchment). F-type streams are often laterally unstable with high bank erosion rates and very high width/depth ratios caused by channel adjustments initiated by down-cutting. Streams classified as "G" or "gully" types were deeply incised in surrounding landforms (i.e., had high entrenchment) but had low width/depth ratios and typically had moderate gradients.

Table 1. Descriptions of general Rosgen (1996) stream types found in the study area and delineative criteria for their broad-level classification.

Stream type	General description	Entrench-ment ratio	W/D ratio	Sinuosity	Slope	Landform/ soil features
Aa	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4 (low)	<12 (low)	<1.1 (very low)	>0.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams with vertical steps and scour pools. Waterfalls often present.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4 (low)	<12 (low)	<1.2 (low)	0.04 to 0.10	High relief. Erosional or depositional and bedrock forms. Entrenched and laterally confined streams that have cascading reaches. Frequently spaced pools associated with step/pool bed morphology.
B *	Moderately entrenched, moderate gradient, riffle dominated channels with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2 (moderate)	>12 (mod.)	>1.2 (mod.)	0.02 to 0.039	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains.	>2.2 (high)	>12 (mod. to high)	>1.4 (high)	<0.02	Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
F	Entrenched, meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4 (low)	>12 (high)	>1.4 (mod.)	<0.02	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering, often laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4 (low)	<12 (low)	>1.2 (mod.)	0.02 to 0.039	Gullies, step/pool morphology with moderate slopes and low width/depth ratio. Narrow valleys or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

* B channels with slopes (gradients) outside the typical range (0.02-0.039) are designated as Ba-types for slopes $\geq$0.04 and Bc-types for slopes<0.02.

3.1.1. Lower South Fork Coquille River

The lower South Fork was broken into 8 distinct reaches that varied in length from 2.88 to 5.23 miles (Table 2; Figure 3). The 15.14 miles of river channel between the mouth and a major bend just above the confluence with Dement Creek was comprised of three reaches that were each classified as predominantly C-type channels with intrusions of type F segments. From the bend above Dement Creek (hereafter referred to simply as "Dement") to the Forest Service boundary, five reaches of the river had what appeared to be predominantly F-type channels mixed with intrusions of B_c or C-type segments. Within all eight reaches, and particularly for the three below Dement, the Level I analysis did not always allow us to discriminate between type F and other stream segment types with a high degree of confidence. This was because in many instances low channel slopes and the flashy hydrology of the South Fork made it difficult to identify the degree to which channel incision would prevent the river from accessing its floodplain at high flow.

In order to facilitate our Level II, Level III, and other analyses of mainstem conditions, each of the eight reaches of the lower South Fork was broken into 5-13 sub-reaches based on locations of significant tributaries and changes in stream orientation. This yielded 67 channel segments (sub-reaches) that averaged slightly more than a half mile in length. Level I channel types for each of these sub-reaches were visually confirmed during foot and kayak-based reconnaissance of the river during summer in 2001 (see Appendix Table A1) as a supplement to our office-based analyses. Ground-level photos taken within each sub-reach during that reconnaissance effort documented prevailing conditions and should prove useful to the CWA in the future (see Appendix B). An ArcView GIS layer giving the locations of the 8 reaches and 67 sub-reaches is on file at the CWA's office in Coquille, Oregon.

Table 2. Level I stream types (Rosgen 1996) for reaches of the lower South Fork Coquille River. Stream classification was based on interpretations of 7.5-minute USGS topographic maps and 1:12000-scale color air photos taken in 1997, as well as brief ground-level reconnaissance during 2001.

Reach	Reach code	No. sub-reaches	Length (mi)	Start elev.	End elev.	Stream order	Entrench-ment ratio	W/D ratio	Sinu-osity	Slope (%)	Rosgen type(s)
Mouth - Middle Fork	SFC-1	8	4.73	11	20	5	high	moderate	1.19	<0.1	C
Middle Fork - Broadbent	SFC-2	9	5.23	20	36	4	high or low	mod. - high	2.14	0.1	C/F
Broadbent - Dement	SFC-3	7	5.18	36	57	4	high or low	mod. - high	1.55	0.1	C/F
Dement - Gaylord	SFC-4	5	3.66	57	75	4	mod. to high	moderate	1.10	0.1	F/Bc
Gaylord - Rowland	SFC-5	10	4.20	75	121	4	high or low	mod. - high	1.34	0.2	F/C
Rowland - Woodward	SFC-6	8	4.31	121	195	4	mod. to high	moderate	1.02	0.3	F/Bc
Woodward - Mill	SFC-7	7	2.88	195	250	4	mod. to high	moderate	1.26	0.3	F/Bc
Mill - USFS Boundary	SFC-8	13	4.57	256	319	4	mod. to high	moderate	1.31	0.3	F/Bc

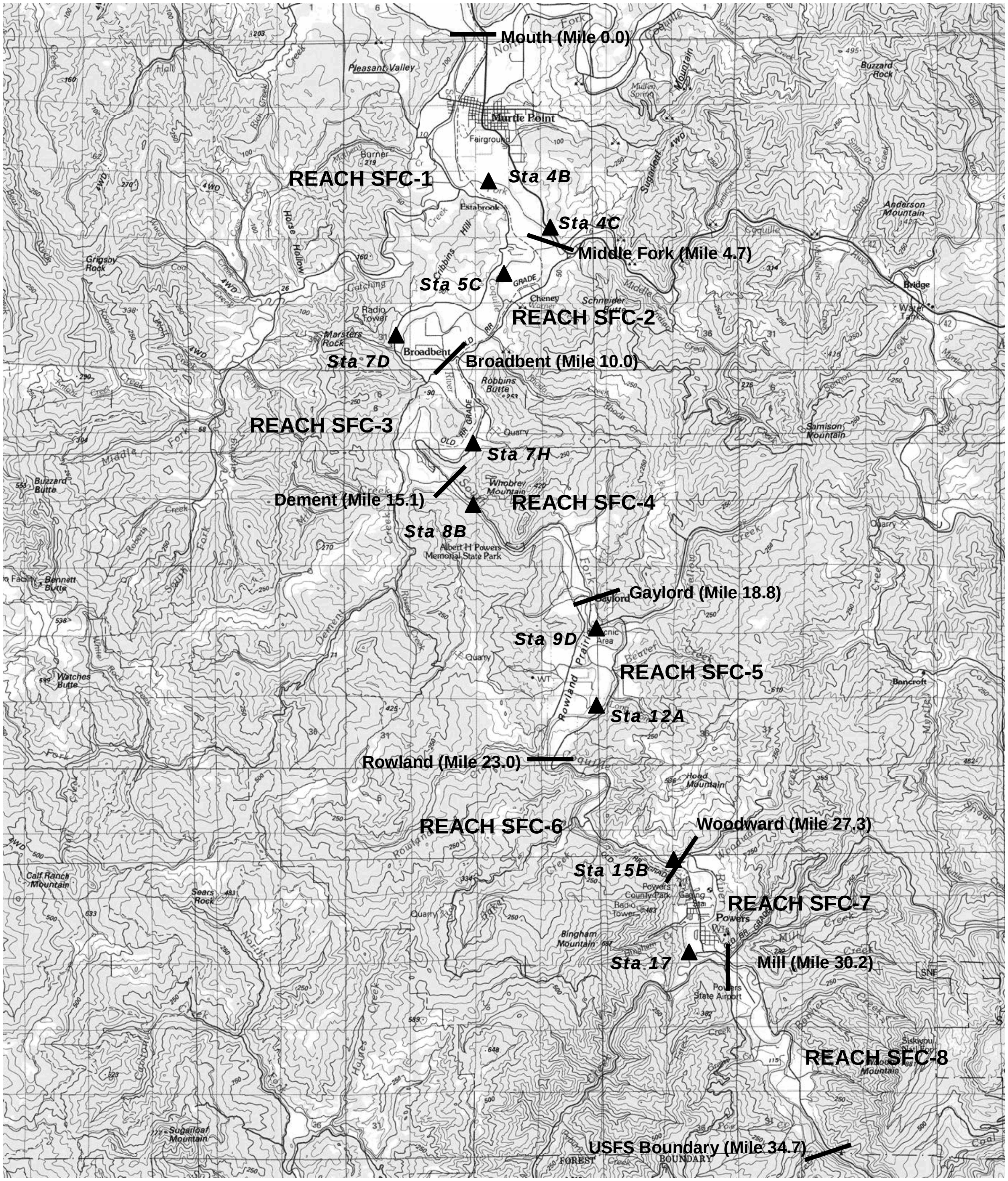

Figure 3. Location map for reaches of the lower South Fork Coquille River and associated study sites (stations). Reaches are identified by alpha-numeric codes beginning with "SFC" and are separated by bold lines that designate reach boundaries. Stations that were a focus of Rosgen Level II and Level III analyses are identified as solid triangles.

3.1.2. Streams in the Dement, Yellow, and Hayes Creek Watersheds

Streams identified as perennial on Oregon Department of Forestry maps of the three tributary watersheds within the study area were broken into a total of 86 reaches based on the locations of major tributary junctions, distinct changes in Rosgen channel types, or substantial shifts in stream orientation (aspect). When subjected to our Level I analysis these reaches were most frequently classified as steep Aa and A-type channels or moderately steep B channels (Table 3), but what appeared in air photos to be strongly entrenched F and G-type channels were also present. What we classified as F and G channels were rather extensive in the Dement Cr. system, where they may reflect past stream down-cutting associated with historic splash damming on Dement Cr. and/or upstream extension of channel down-cutting reported to have occurred along adjacent segments of the mainstem South Fork. Several of these channels appeared to have experienced bed aggradation during recent floods.

Table 3. Numbers of reaches (with stream miles given in parentheses) classified into each of five general Rosgen (1996) channel types found within the Dement Cr., Yellow Cr., and Hayes Cr. watersheds. Stream classification was based on interpretations of 7.5-minute USGS topographic maps and 1:12000-scale color air photos taken in 1997. Field verification was limited by access to private land.

Watershed	Rosgen channel types (photo-interpreted)				
	Aa	A	B	F	G
Dement Cr.	16 (8.24)	9 (4.09)	8 (3.30)	8 (4.12)	3 (2.12)
Yellow Cr.	14 (6.92)	5 (1.53)	8 (2.83)	2 (0.70)	1 (0.76)
Hayes Cr.	8 (3.48)	2 (1.16)	2 (1.52)	---	1 (0.27)
All three tributaries	*38 (18.64)*	*15 (6.78)*	*18 (7.65)*	*10 (4.82)*	*5 (3.15)*

ArcView GIS layers delineating the locations of the study reaches within the Dement Cr., Yellow Cr., and Hayes Cr. watersheds are on file with the CWA. Rosgen Level I channel types and other office-based data for the reaches are given in Appendix Table A2.

3.2. LEVEL II -- MORPHOLOGICAL DESCRIPTION

The Level II assessment within Rosgen's hierarchical approach to evaluating stream morphology focuses on gathering and then analyzing detailed field data in order to verify, calibrate and refine results of the Level I assessment. Particular emphasis is placed on selecting and evaluating representative (or "reference") channel segments from among those delineated during the Level I assessment so that results of the Level II work can be systematically extrapolated to the entire area under study. At least one representative channel segment of each Rosgen type identified during the Level I assessment is usually included. Level II data collected on each representative segment include a variety of channel measurements from which five metrics can be calculated: an entrenchment ratio, a width/depth ratio, stream sinuosity, a channel slope, and the median particle size of channel substrates (the D_{50}). Values for these metrics are then compared to specific classification criteria and the correct Level II Rosgen type is assigned, both to the representative channel segment and to similar segments elsewhere in the study area. Level II Rosgen types each incorporate a numeric code that indicates the substrate size class within which the D_{50} falls: 1 (bedrock), 2 (boulders), 3 (cobble), 4 (gravel), 5 (sand), or 6 (silt/clay).

Our Level II work was restricted to the mainstem South Fork and followed the standard pattern just described with two exceptions. First, *we supplemented the basic data collection effort with an extensive survey of the entire mainstem South Fork from the National Forest boundary down to the mouth.* This survey systematically collected a variety of in-channel and riparian data that helped us better understand how conditions varied along the mainstem and assured that channel segments selected for Level II assessment would be both representative and inclusive of the kinds of channel instability problems of concern to the CWA. Much of the data collected during this survey was also used in our Level III analyses (see Section 3.3.1) or central to our SHADOW modeling of shade along the river (see Section 4). *Our Level II effort also went beyond the basic Rosgen approach in that an integrated flood frequency and hydraulic analysis was performed as part of our assessment of each representative channel segment.* This analysis was conducted because we found few reliable field indicators of bankfull river stage within the channel segments selected for Level II assessment.

3.2.1. Extensive Survey of the Lower South Fork

Our extensive survey of the South Fork was conducted on foot or by kayak, depending on access and channel conditions. Within each of the 67 sub-reaches downstream of the National Forest boundary, we established 3-4 evenly spaced cross-sectional transects of the river and its adjacent riparian corridor. At each transect (206 total) we measured the river’s wetted and active channel width as well as several characteristics of the vegetation on each riverbank. These riparian characteristics included the percentage of stream and channel width overhung by vegetation, the dominant type of vegetation shading the river, the distance from the channel to the dominant shade-producing vegetation, the height of the bank at the base of this vegetation, and the height of the vegetation itself. Significant areas of eroding, raw, or poorly vegetated banks encountered within the sub-reaches during the survey were delineated on air photos or recorded as GPS coordinates, mapped over digital orthophotos, and ultimately incorporated into an ArcView GIS layer provided to the CWA.

Results of the extensive survey are given in Appendix C. In addition to informing our selection of channel segments for detailed Level II analyses and to providing key data for our SHADOW modeling (see Section 4), the survey gave us insights related to bank stability issues of concern to the CWA. These included:

- Riverbanks that support woody riparian vegetation and that do not appear to be eroding to an appreciable degree are more abundant along the South Fork than are eroding banks, even in the river reaches exhibiting the greatest levels of bank instability.
- Although eroding banks were distributed throughout the lower river, their frequency, severity, or both, were greatest in reaches below Gaylord (i.e., SFC-1 through SFC-4) and particularly in the reaches below Dement (SFC-1 through SFC-3).
- Areas of the South Fork below Dement that experienced the most severe bank erosion during recent floods no longer have a natural buffer of woody riparian vegetation to protect deep valley soils against removal by the river during floods.
- In addition to poor riparian conditions, some of the most severely unstable channel segments below Dement appear to have been influenced by changes in the river’s alignment or behavior following placement or repositioning of rock “bank protection” structures.
- The severity of recent bank erosion at multiple locations along the lower river, where some raw banks were 25-30 feet tall in 2001, suggests that the causes are likely systemic (operating at a large spatial scale) as well as local.
- Dense patches of scouler willow (Salix scouleriana) were growing in lower to mid-bank positions at a substantial proportion of stable sites along the South Fork below Dement, suggesting that there may be an important role for this or other willow species in maintaining or restoring channel stability in the area.
- Livestock have been fenced back from the South Fork in many areas, but they continue to damage riparian vegetation and streambanks along portions of the lower river, including at least two sites where the CWA has sponsored bank stabilization projects.

3.2.2. Representative Channel Segments

Following the extensive survey, we selected a sample of 10 (15%) of the lower South Fork's 67 sub-reaches to serve as representative channel segments for our quantitative Level II assessment. This sample captured the range of conditions and Rosgen channel types present along the river as well as providing an opportunity to examine potential geomorphic differences between areas with differing levels of bank instability, an issue also addressed in our Level III work. Locations of the selected sub-reaches are shown in Figure 3 (see page 7), with each "station" representing the site where an intensively surveyed channel cross-section served as the focal point of our morphological, hydrologic, hydraulic, and other analyses of conditions within a sub-reach. Ground-level photos of the stations are given Appendix D, as are data summaries from level-and-rod surveys conducted within each selected sub-reach. Tabular and graphical summaries of Wolman (1954) pebble counts of channel substrates at the stations and at other selected locations on the river are provided in Appendix E.

We used standard methods (Harris et al. 1979) and data from nearby USGS stream gauges to develop synthetic flood exceedance curves for each of the 10 representative sub-reaches, then simulated hydraulic conditions expected to occur within the sub-reaches during 1.25, 2, 5, 10, 25, 50, and 100-year floods. The hydraulic simulations for each sub-reach were performed by incorporating the estimated flood flows and our level-and-rod field measurements of channel geometry into a HEC-RAS computer model. Results for the station evaluated within each sub-reach included multiple parameters associated with bankfull conditions (flow, river stage, width, depths, cross-sectional area, and water velocities), as well as an estimated recurrence interval for the magnitude of flood required to overtop the riverbanks and spread water across any extended floodplain. For example, bankfull flows estimated for the 10 stations ranged from 10,306 cfs (Sta 17 at RM 29.4; near Powers) to 23,573 cfs (Sta 4B at RM 3.3; near Myrtle Point); over-bank floods were predicted to occur at intervals of 2 years to greater than 100 years, depending on the station. More complete summaries of our modeling are given in appendices F and G.

When integrated with more conventional Level II analyses (Rosgen 1996), our modeling results allowed classification of the representative sub-reaches into specific channel types. The types included B3c, B4c, C3, C4/F4, F5/C5, and F3, with channels that were moderate to deeply entrenched in more resistant parent materials near the National Forest boundary transitioning into channels of variable entrenchment in highly erodible parent materials downstream of Dement (Table 4). Three of the five sub-reaches evaluated downstream of Dement (RM 15.1) had what could be described as “transitional” channels whose entrenchment within the surrounding valley floor placed them at or very near the boundary between the Rosgen C-type and the F-type. Two of these “transitional” sub-reaches (7D and 7H, both classified as C4 or F4 channels) had the most severe bank erosion problems of the ten sub-reaches included in our Level II assessment. The third “transitional” sub-reach (4C, classified as an F5 or C5 channel) may be affected by tidal backwatering during major floods and thus (1) more likely to overtop its banks than suggested by our modeling and (2) partially buffered against erosive forces that would otherwise be very high.

Table 4. Rosgen Level II channel types and associated information for 10 representative sub-reaches of the lower South Fork Coquille River, Oregon, summer 2001.

Reach	Subreach/ station	Station River Mile	Entrench- ment ratio	Width/ depth ratio	Sinuosity	Slope	Channel materials		Channel type
							(mm)	Class	
SFC-1	4B	3.3	>2.2	13	1.19	0.0010	12	gravel	C4
SFC-1	4C	4.5	1.4*	13	1.19	0.0006	1	sand	F5/C5
SFC-2	5C	6.0	>2.2	11	2.14	0.0024	12	gravel	C4
SFC-2	7D	8.9	>2.2**	53	2.14	0.0013	7	gravel	C4/F4
SFC-3	7H	11.9	>2.2**	23	1.55	0.0024	14	gravel	C4/F4
SFC-4	8B	15.6	1.4***	18	1.10	0.0038	15	gravel	B4c
SFC-5	9D	19.4	>2.2	17	1.34	0.0021	16	gravel	C4
SFC-5	12A	22.0	>2.2	24	1.34	0.0014	42	cobble-gravel	C3
SFC-6	15B	27.1	1.4	12	1.02	0.0081	60	cobble-gravel	B3c
SFC-7	17	29.4	1.3***	23	1.26	0.0025	39	cobble-gravel	F3

* Flood levels at Station 4C may be tidally affected. This would cause major floods to overtop the banks here.

** Stations 7D and 7H exhibited severe bank erosion and hydraulic analyses suggest their banks might not be over-topped by a 100-year flood. However, increasing flow enough to double the maximum cross-section depth predicted for bankfull discharge would inundate the floodplain.

*** Hydraulic analyses suggest that a 100-year flood may overtop the banks at stations 8B and 17. However, increasing flow enough to double the maximum cross-section depth predicted for bankfull discharge would not inundate the floodplain.

Coupled with the Level I assessment, results of our evaluation of representative sub-reaches suggests that the three major reaches of the South Fork downstream of Dement (SFC-1 through SFC-3) have predominantly C4 channels with intruding segments classified as C5 or “transitional” F4 or F5 types (Table 5). Upstream, the river reach between Dement and Gaylord (SFC-4) has a B4c channel with F4-type intrusions, and the reach from Gaylord up to Rowland

(SFC-5) has an F4-type channel with intruding C4 segments. From Rowland upstream to the National Forest boundary (in reaches SFC-6 through SFC-8), the river has a predominantly F3 channel with intrusions of somewhat less entrenched B3c-type segments.

Table 5. Rosgen Level II channel types and associated information for major reaches of the lower South Fork Coquille River, Oregon, summer 2001.

Stream	Reach	No. sub-reaches	Length (mi)	Entrench-ment	Width/ Depth	Sinu-osity	Slope (%)	Dominant substrate(s)	Rosgen type(s)
Mouth - Middle Fork	SFC-1	8	4.73	typ. 2.2+	13	1.19	<0.1	gravel-sand	C4/C5
Middle Fork - Broadbent	SFC-2	9	5.23	typ. 2.2+	11-53	2.14	0.1	gravel-sand	C4/F4
Broadbent - Dement	SFC-3	7	5.18	typ. 2.2+	11-23	1.55	0.1	gravel	C4/F4
Dement - Gaylord	SFC-4	5	3.66	1.4 - 2.2	18	1.10	0.1	gravel	B4c/F4
Gaylord - Rowland	SFC-5	10	4.20	1.3 - 2.2+	17-24	1.34	0.2	gravel	F4/C4
Rowland - Woodward	SFC-6	8	4.31	1.3-1.4	12-23	1.02	0.3	cobble-gravel	F3/B3c
Woodward - Mill	SFC-7	7	2.88	1.3-1.4	12-23	1.26	0.3	cobble-gravel	F3/B3c
Mill - USFS Boundary	SFC-8	13	4.57	1.3-1.4	12-23	1.31	0.3	cobble-gravel	F3/B3c

3.3. LEVEL III -- ASSESSMENT OF STREAM CONDITION AND DEPARTURE

Level III analyses within Rosgen's hierarchical approach to assessing stream morphology examine selected hydrologic, biological, ecological, and human factors affecting the condition of representative channel segments and the river system. The intent is to describe (1) existing channel stability and function, and (2) the degree to which the existing condition deviates from a dynamically stable, "potential" state (Rosgen 1996). Existing channel stability and function are evaluated through a combination of field-based measurements and office analyses of specific factors affecting or reflecting current conditions within the same representative channel segments evaluated in the Level II assessment. Deviations from the "potential" state are usually judged by comparing current conditions to those in undisturbed "control" streams when such streams exist. When there is no valid control stream, a sense of the potential state is developed by making comparisons among channel segments with similar morphologies but differing levels of disturbance, through historical reconstruction, and/or by using quantitative relationships provided by Rosgen (1996) to develop approximations of "potential" channel geometry. In theory, the "potential" condition provides a template that can be used to describe departures from dynamically stable conditions and to help guide efforts to restore the stability and function of an altered channel.

3.3.1. Existing River Conditions

We used methods outlined by Rosgen (1996), supplemented by a technique for assessing riverbank stability described in the federal Stream Corridor Restoration Handbook (FISRWG 1998), for our Level III analysis of existing conditions at each of the 10 representative channel segments included in our Level II assessment. Results of this Level III analysis, summarized in Appendix Table H1, are described briefly below. The reader is referred to Appendices F, G, and H for more detailed results on each of the sub-reaches.

Riparian vegetation. Vegetation bordering the representative channel segments varied from dense stands of deciduous trees with a brush/grass understory to areas supporting only grazed grasses with scattered brush. The three segments with the least vigorous and most shallow-rooted streamside vegetation (7D, 7H, and 12A) also had the widest and least stable channels (see below).

Streamflow regime. Each representative channel segment, and the lower South Fork Coquille River as a whole, had a perennial flow regime with seasonal variations in discharge dominated primarily by stormflow runoff.

Stream size and order. The South Fork is a 4th-order stream at each of the 8 representative segments above the Middle Fork confluence and a 5th-order stream at the 2 segments below that confluence. Bankfull channel widths for the 10 segments varied from 102 to 383 feet, placing them in Rosgen's S-8 to S-10 stream size classes, but did not follow a pattern of steady increases in the downstream direction. All three 4th-order segments above the Middle Fork confluence that had poor channel stability (see below) had wider channels than did either of the two 5th-order segments evaluated downstream of the Middle Fork.

Occurrence of Organic Debris. Organic debris was generally scarce within the 10 channel segments and when present had an insignificant effect on river morphology. It was classified as absent from one segment (subreach 12A), infrequent at eight segments, and moderate at one segment (subreach 7H).

Depositional Patterns. Depositional features within each representative channel segment examined along the South Fork were dominated by a combination of point bars and side bars, although diagonal and mid-channel bars were occasionally present. Rosgen categories assigned to the depositional features within the segments included B-1 (point bars), B-2 (point bars with few mid-channel bars), B-4 (side bars), and B-5 (diagonal bars).

Meander patterns. The meander patterns of the 10 representative segments were classified with reference to the larger river reaches within which they were embedded. This was done because sharp bends in the river (a dominant contributor to the South Fork's sinuosity) often formed sub-reach boundaries and would otherwise have been only weakly accounted for in this portion of our assessment. The meander pattern of each representative segment was classified as irregular (Rosgen category M-3), particularly within study reaches SFC-2 and SFC-3. In these reaches the river exhibited an unusual pattern in which it appeared primarily to be deflected from one distant, erosion-resistant surface to another as it moved across the valley floor. This unusual pattern was evident at two of the three representative segments (5C and 7H) examined within these two reaches. The third segment examined within either SFC-2 and SFC-3, sub-reach 7H, had the greatest level of channel instability seen in the entire study area and had experienced severe bank erosion, channel widening, and increases in sinuosity during recent floods.

Channel Stability. The stability of the representative channel segments was documented by assigning each a Pfankuch (1975) stability rating, and qualitatively assessing their sediment supply, vertical bed stability, and width/depth ratio condition. These are standard procedures in a Rosgen Level III analysis.

Pfankuch stability ratings for the 10 representative channel segments ranged from 83 (good) to 144 (poor), with good ratings at 4 of the 5 segments above Dement and fair or poor ratings at the segments below Dement. The sediment supply was judged moderate and the riverbed either vertically stable or of unknown vertical stability in the segments above Dement. Below Dement, the evaluated segments had moderate to high sediment supplies with mixed indicators of channel aggradation or degradation. Width/depth ratios were considered to be in the "normal" range at seven of the representative segments, "high" at two (sub-reaches 7H and 17), and "very high" at one (sub-reach 7D). Two of the segments with above-"normal" width/depth ratios (subreaches 7D and 7H) were downstream of Dement, had eroding banks, and were rated as having poor channel stability. The third evaluated segment with a width/depth ratio considered notably above-"normal" (sub-reach 17) was situated immediately downstream of a large South Fork tributary (Salmon Creek) that had clearly influenced channel conditions.

Riverbank stability. The potential for riverbank erosion within each of the 10 representative channel segments was rated using two methods, one outlined by Rosgen (1996) and the other recommended in the Stream Corridor Restoration Handbook (FISRWG 1998). Rosgen's method uses on-site measurements and quantitative criteria to classify bank erodibility and the near-bank stress caused by hydraulic forces into qualitative ratings. The Handbook method combines information on bank heights, bank angles, and the geotechnical properties of riverbank soils to develop bank stability charts that allow one to rate bank stability based on field measurements of bank height, bank angle, and local soil type (Figure 4; see Appendix F). Banks that the stability charts classify as "unstable" can be expected to fail after flood events when the channel banks become saturated and toe erosion occurs. Banks that the charts show as being "at risk" may fail every 2-5 years for the same flood conditions. Stable banks do not typically fail by mass wasting but may erode and over-steepen, especially on the outside of stream meanders, and eventually fail.

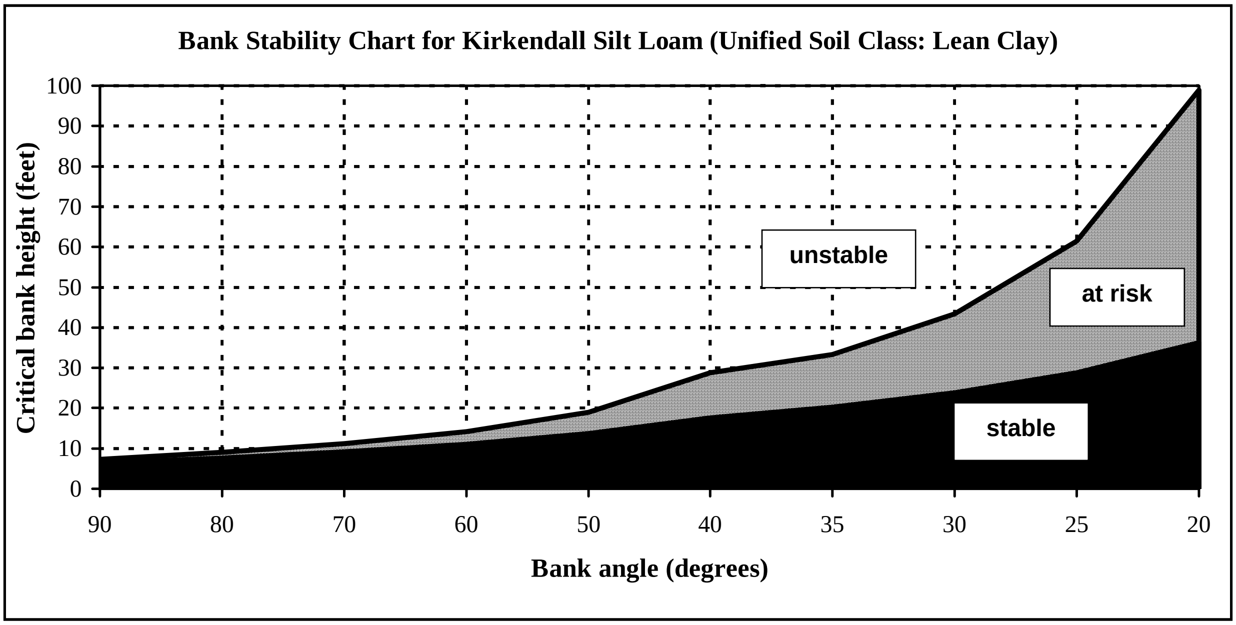

Figure 4. Example of bank stability chart developed using the method recommended in the Stream Corridor Restoration Handbook (FISRWG 1998). See Appendix F for additional information on the development and use of stability charts for riverbanks along the South Fork.

Results of our assessment of riverbank stability were relatively consistent across the two methods employed (Table 6). Both the Rosgen and Handbook-type results indicate that the representative channel segments evaluated downstream of Dement (in reaches SFC-1 through SFC-3) generally had riverbanks at greater risk of erosion than did segments above Dement. Geotechnical instability (as indicated by the Handbook method) was not as severe as field personnel had speculated while collecting data in several of the segments downstream of Dement, apparently because tall riverbanks that experienced mass (geotechnical) failures during recent floods quickly retreated to stable angles of repose. Those banks will again become geotechnically unstable if bank heights increase due to additional river down-cutting or if lateral channel migration causes sufficient toe erosion to over-steepen them.

Table 6. Riverbank stability ratings for 10 representative channel segments on the lower South Fork Coquille River, Oregon, 2001.

Reach	Subreach/ station	Location (River Mile)	Rosgen near-bank stress	Rosgen bank erodibility	Geotechnical bank stability
SFC-1	4B	3.3	high	high	stable to at risk
SFC-1	4C	4.5	high	high	stable to at risk
SFC-2	5C	6.0	high	high	stable
SFC-2	7D	8.9	very high	extreme	stable to at risk
SFC-3	7H	11.9	high	very high	stable to at risk
SFC-4	8B	15.6	moderate	moderate	stable
SFC-5	9D	19.4	moderate to high	moderate	stable
SFC-5	12A	22.0	moderate to high	moderate	stable
SFC-6	15B	27.1	moderate	low	stable
SFC-7	17	29.4	moderate	moderate	stable

Direct Channel Alterations. Direct alterations of the lower South Fork's channel have consisted primarily of (1) hardening of riverbanks with rock structures in order to protect specific, localized sections of bank from erosion; (2) construction of river access roads through both riparian vegetation and steep river banks; and (3) gravel removal. Bank protection structures are absent, or very nearly so, from most of the delineated sub-reaches but are quite evident in others. Of the representative channel segments examined in detail, sub-reaches 7D and 7H had relatively recent rock work that may have played an unintended role in channel responses to the 1996 flood. In both cases, it appeared that downstream shifts in channel alignment associated with the rock work may have combined with geotechnically sensitive bank conditions to exacerbate severe erosion that occurred during the flood. Access roads are present at a frequency of about one every couple of miles along the lower mainstem and one was found within each of three of the representative channel segments (subreaches 7D, 8B, and 9D). Commercial gravel mining occurs within study reaches SFC-3, SFC-4, and SFC-5 and has been permitted in recent years to scalp up to 85,000 cubic yards of material from bars if it can be removed without lowering bar elevations below specified criteria (T. Morrow, ODSL, pers comm.). This mining has an unknown relationship to sediment supply and an undocumented effect on channel processes in the South Fork. It occurs in one of the representative channel segments – sub-reach 8B.

3.3.2. Departure from Potential River Conditions

There are no undisturbed or lightly disturbed “control” rivers suitable for use in an analysis of the degree to which the study reaches or sub-reaches of the lower South Fork differ from their potential condition. For this reason, we conducted our assessment of the river’s departure from its potential state by using some of the alternative methods described earlier in Section 3.3. We first examined existing longitudinal variation in selected river conditions for patterns suggestive of systemic shifts away from stable conditions. We then used historical records and air photos to reconstruct changes that have occurred on the lower South Fork, and utilized quantitative relationships from Rosgen (1996) to approximate selected aspects of “potential” channel geometry.

Existing Patterns: Channel Profile, Widths and Materials. Down-cutting and other disturbances that have been reported for the lower South Fork have the potential to change a river channel’s profile, width, and bed materials. We were unable to locate an accurate longitudinal profile of the lower South Fork’s channel (the one given in Section 2 was based on crude data of uncertain accuracy), but did have data on longitudinal variability in channel widths and materials from our Level II assessment. These data were plotted for the entire length of the lower river so that they could be inspected for patterns that might provide insights on riverine processes.

The width of the lower South Fork was highly variable at multiple spatial scales in 2001 (Figure 5). Channel widths we measured at a total of 206 points along the river varied by a factor of 7 between the mouth and the National Forest boundary, by factors of 2-4 within study reaches, and by factors of 1.1-2.5 within individual sub-reaches. This high degree of variability reflects frequent channel adjustments and seems to indicate a substantial capacity for channel widening (or narrowing) within at least some portions of the study area. There is also one pattern in the variation of channel widths along the length of the river that is intriguing but of uncertain diagnosticity. The mean channel widths of sub-reaches vary in sequential fashion along several extended segments of the river and particularly within reaches SFC-2, SFC-3, and SFC-5. In each of these three reaches, the sub-reach with the greatest mean width is followed downriver by a sequence of sub-reaches with progressively narrower channels. We are unsure if this reflects underlying patterns of change in channel slope, legacies of past episodes of channel adjustment related to down-cutting, locations of key sediment source areas, lingering effects of gravel mining, or simply random patterns. Explanations for the pattern of elevated then declining channel widths might vary among the three reaches in which the pattern is most pronounced. The widest sub-reaches in these three reaches included:

- *Sub-reach 7D within reach SFC-2* was the least stable segment of the mainstem.

- *Sub-reach 7K in reach SFC-3* was immediately below Dement Creek (a major sediment source), had severe bank erosion at its upstream end, and contained a major bar subject to scalping by commercial gravel operators.

- *Sub-reach 11 in reach SFC-5* had the greatest mean channel width measured in the study area, a stable but altered channel, and a massive gravel bar that had been modified by commercial gravel operators to the point that it was a migration barrier to fish during periods of low flow.

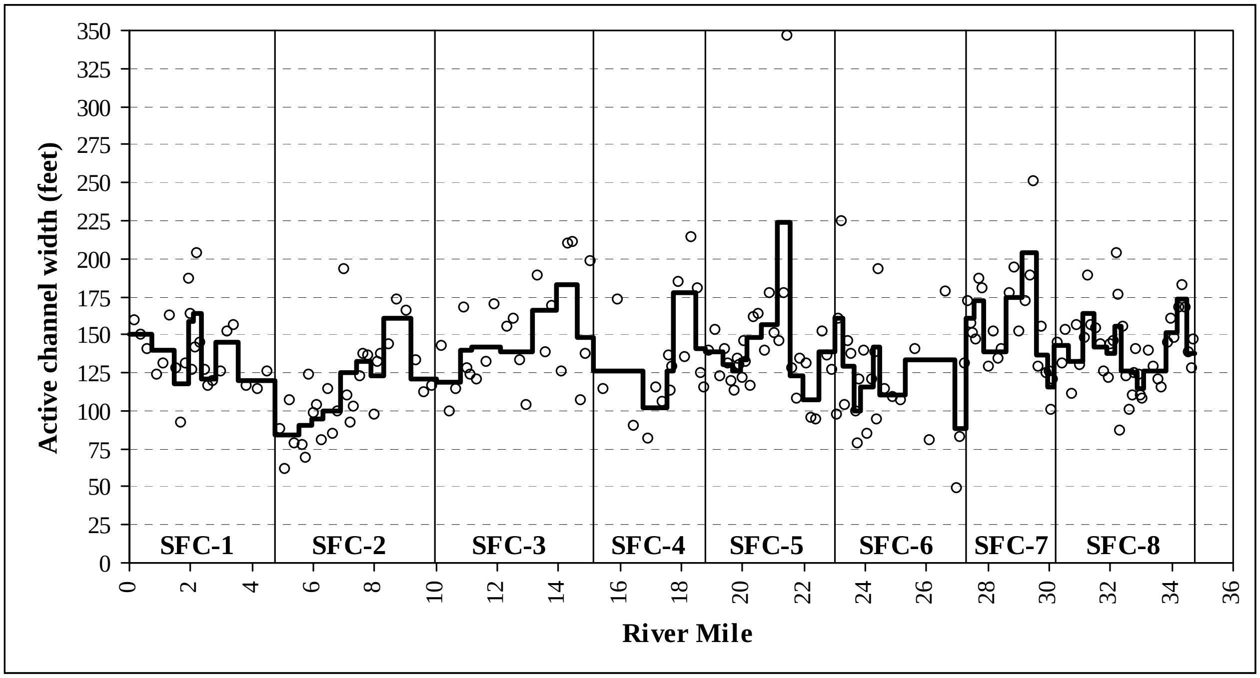

Figure 5. Active channel width versus River Mile for the lower South Fork Coquille R., Summer 2001. Open circles represent individual field measurements of channel width. The bold line represents variations in mean channel widths among individual sub-reaches of the river. Study reaches within which the sub-reaches were nested are indicated by alpha-numeric codes beginning with "SFC-".

Median (D_{50}) diameters of channel particles within riffle areas followed a typical pattern of decline as channel slopes fell in the down-river direction (Figure 6) and thus offer little diagnostic information other than to indicate the absence of clearly anomalous conditions. We did note progressive increases in the levels of fine streambed sediment with increasing proximity to the mouth, increases that were particularly large downstream of Dement in reaches SFC-1 through SFC-3 (see Appendix Table H2). The increases in fine sediment are suspected to reflect both natural deposition in response to decreasing channel slopes and the contributions of fine material from lower river tributaries and eroding banks along the mainstem.

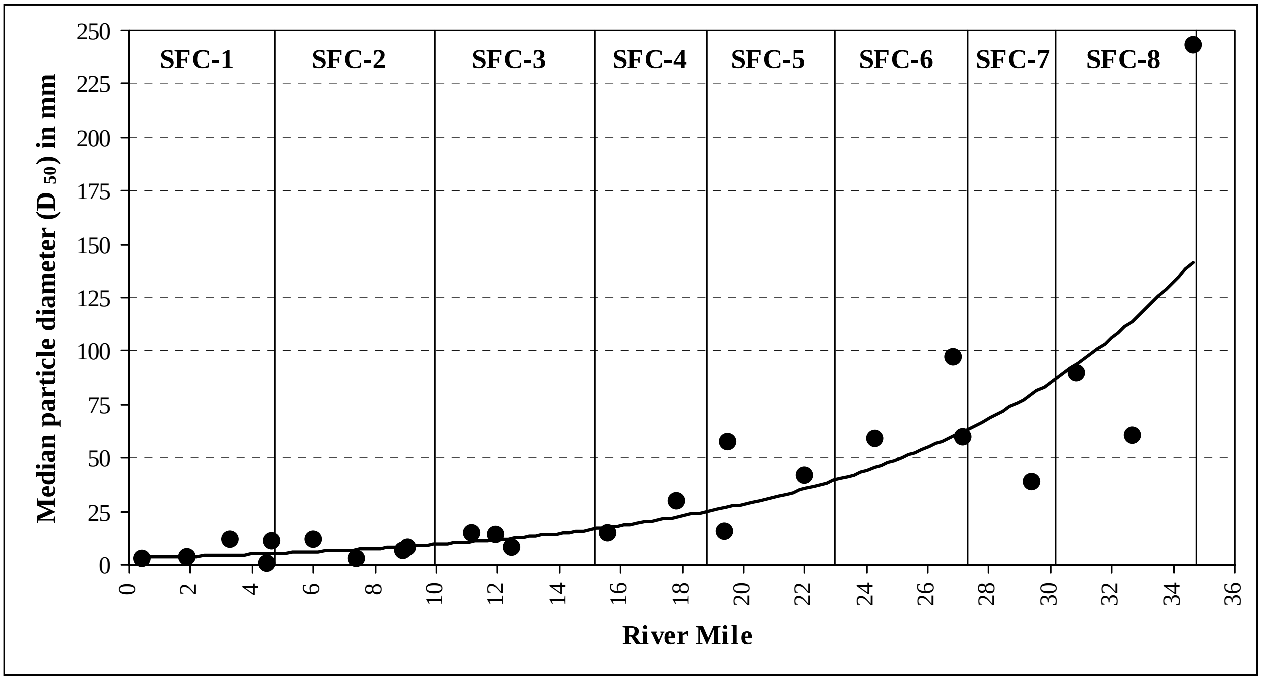

Figure 6. Median (D_{50}) particle sizes versus River Mile for Wolman pebble counts conducted on the lower South Fork Coquille River, Summer 2001. Locations of study reaches are indicated by alpha-numeric codes beginning with "SFC-".

<u>Existing Patterns: Longitudinal Changes in Gravel Bar Area</u>. The potential interplay between sediment supply, gravel mining, channel incision, and bank erosion along the lower-most reaches of the South Fork is an important issue that needs to be resolved. Although not a definitive approach to addressing the issue, we used data from our 206 channel transects (see Section 3.2.1) to estimate the areas of gravel surfaces exposed during low flow along the river. Our intent was to check for differences in the surface areas of bars that might be (1) evident at the study reach scale and (2) suggestive of a severe discontinuity in sediment availability. The result of this assessment was that we did not see large declines in bar area per mile of channel in the reaches below Dement (SFC-1 through SFC-3; the reaches downstream of current mining operations) when compared to study reaches farther up river. In fact, our estimates of exposed bar area/mile for each of the lower three reaches were similar to those in most of the remainder of the study area. We did, however, find that the area of exposed bar surfaces was lower in reach SFC-4 than in the other seven reaches. Reach SFC-4, between Dement and Gaylord, accounts for a sizeable portion of the section of river mined for gravel.

Existing Patterns: Longitudinal Changes in Riparian Vegetation. Riparian vegetation affects river morphology by contributing woody material to the channel and by helping banks resist erosion by binding them with dense root networks and slowing flood flows, and by encouraging sediment deposition along the channel margins. Changes in riparian conditions along a river can thus influence bank integrity and channel form.

We mapped the lower South Fork's riparian vegetation onto clear overlays of 1:12,000-scale aerial photos taken of the river in 1997, breaking the vegetation along each riverbank into four classes identified in the Oregon Watershed Assessment Manual (WPN 1999): grass/forb, shrubs, sparse trees, and dense trees. Measurements taken from the overlays were then used to estimate the percentages of total riverbank length supporting these classes of vegetation. Results of this analysis are summarized in Figure 7. The photo overlays, which could be used to help select areas for riparian restoration projects, are on file with the CWA .

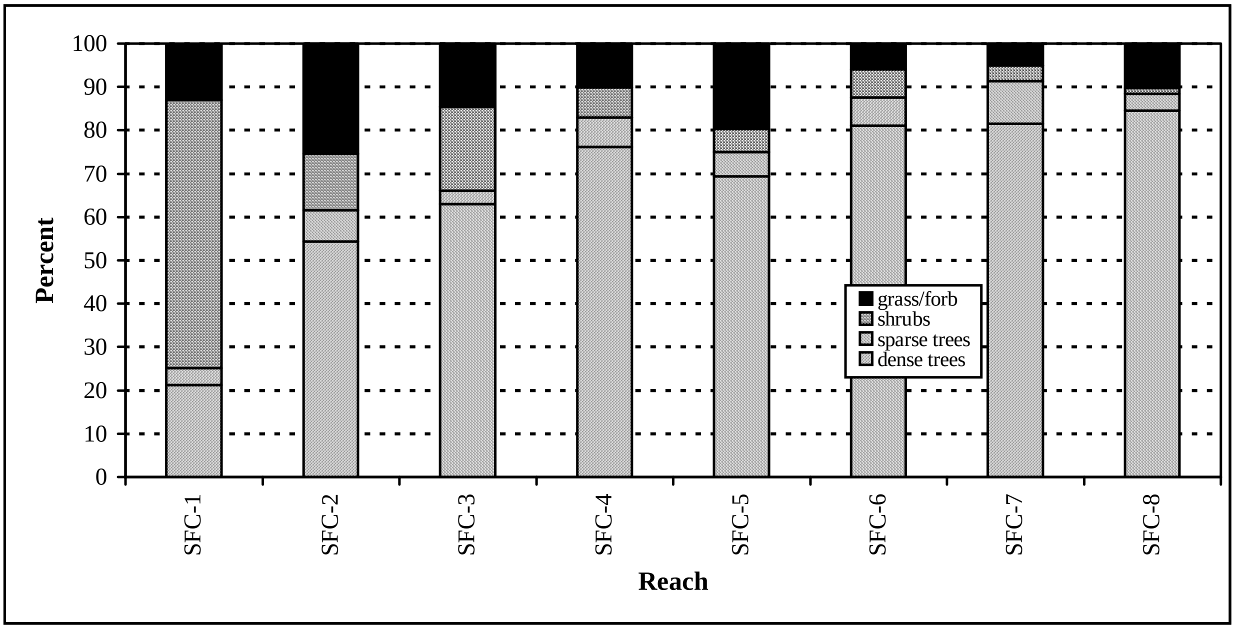

Figure 7. Percent (by riverbank length) for four classes of riparian vegetation along reaches of the lower South Fork Coquille River. Supporting data are given in Appendix Table H3.

Our photo-based analysis of the relative condition of riparian vegetation bordering the lower South Fork suggests several patterns consistent with trends in riparian disturbance and bank stability that were observed in the field or indicated by the analysis of riverbank stability summarized in Section 3.3.1. These patterns include:

- Dense stands of riparian trees were present along most of the South Fork's banks within all but the lower-most study reach (SFC-1), where shrub communities predominated.
- Riverbanks supporting shrub or grass/forb communities with very few or no trees accounted for less than a quarter of the banks within reaches above Dement (SFC-4 through SFC-8) but greater and increasing proportions of the banks as the river passed from Dement to the mouth (from SFC-3 to SFC-1).
- Banks supporting only grass/forb communities, a clear reflection of recent disturbance, were present within each of the study reaches but were most common in reach SFC-2, where channel instability and at-risk banks were most prevalent.

Historic Changes: River Alignment. Channel simplification and reductions in sinuosity are frequently associated with episodes of river down-cutting. While our surveys of the lower South Fork confirm that the river is simplified and in some areas has tall, near-vertical banks, it seemed advisable to examine possible changes in the river's historic meander pattern. Knowledge of such changes would help identify the river's "potential" state and provide insights regarding erosional processes at work in the river as well.

Two sources of information were readily available for examining planform changes that have occurred along the lower South Fork since it was in essentially pristine condition back in the mid-1800s. The first source consisted of multiple property maps available from Coos County that showed the position of the South Fork channel between the mouth and Powers (i.e., study reaches SFC-1 through SFC-6) as measured in about 1870 by General Land Office (GLO) surveyors and in about 1980 by the USGS. The second source was a map developed by Florsheim and Williams (1996) that showed changes in the position of the South Fork channel in the Middle Fork to Broadbent reach (SFC-2) between 1939 and 1992.

We acquired the maps just described, examined them for historical changes in river alignment and channel sinuosity, then used ArcView to digitize and map the channel positions shown on those portions of the maps covering study reaches that experienced significant planview changes over time. All ArcView layers created through this process are on file with the CWA.

Visual inspection and measurements of our digitized versions of river positions shown on the Coos County property maps showed little historic change in the alignment or sinuosity of the South Fork between the mouth and the Middle Fork (reach SFC-1) or between Dement and Powers (SFC-4 through SFC-6). However, substantial differences were evident between the circa 1870 and circa 1980 alignments of the river between the Middle Fork and Dement (reaches SFC 2 and SFC-3). Changes in both channel position and sinuosity occurred along this part of the river between the two periods (Figure 8). Between the Middle Fork and Broadbent (reach SFC-2), the river's sinuosity dropped 14% (from 2.48 to 2.14) as its length decreased from 6.06 miles to 5.23 miles. The circa 1870 channel within reach SFC-2 had a meander pattern that included riverbends that were both more frequent and often more acute than those now present. Reach SFC-3, from Broadbent to Dement, experienced a 5% drop in sinuosity (from 1.63 to 1.55) as its length decreased from 5.45 to 5.18 miles between the two time periods. There were no evident patterns of increase or decrease in channel widths

The changes in river meander patterns and losses of channel length that occurred within study reaches SFC-2 and SFC-3 between the mid-1800s and late-1900s likely reflect multiple changes that have occurred along the lower South Fork and within the river's watershed. For instance, some of the tighter (sharper) meander bends found along reach SFC-2 circa 1870 would be hard to imagine on a river so large without the armoring effect of large woody debris accumulations along the outsides of the bends. Such accumulations are now entirely absent from the lower river. Whatever the exact combination of causes, the losses of river length by themselves, particularly in reach SFC-2, indicate historical down-cutting, increases in channel slope, and associated increases in bank heights.

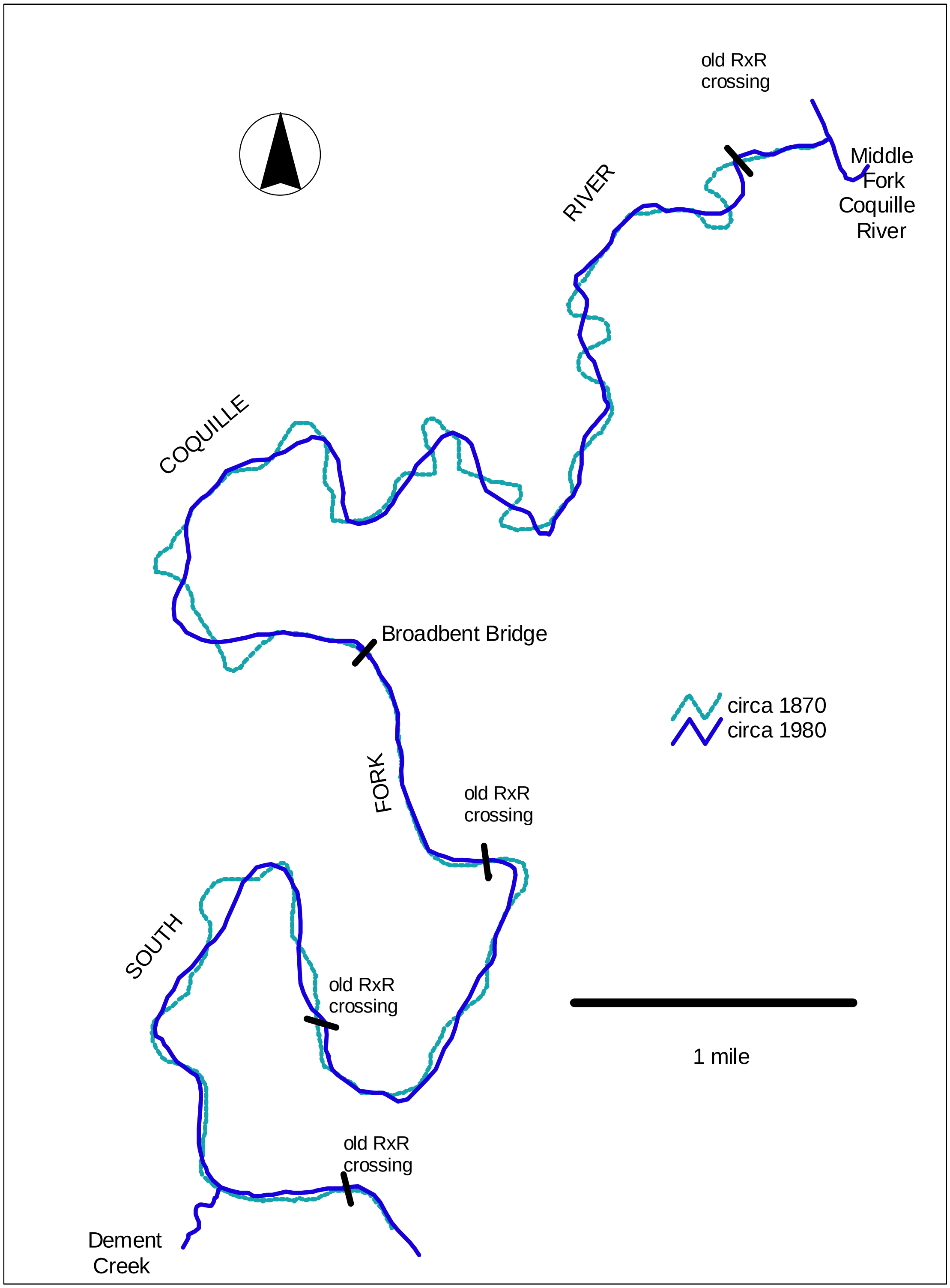

Figure 8. Changes in the alignment of the South Fork Coquille River between the Middle Fork and Dement (study reaches SFC-2 and SFC-3), 1870-1980. River positions given represent channel mid-lines.

Looking closely at planform changes that occurred in the Middle Fork to Broadbent reach (SFC-2) between 1939 and 1992, first mapped by Florsheim and Williams (1996), it is evident that much of the historic change in the lower river meander patterns occurred prior to 1939. Lateral channel migration was evident at multiple locations within this reach between 1939 and 1992, but the basic meander pattern and total reach length remained fairly stable (Figure 9). Varied segments of the reach exhibited relative constancy, channel widening, or channel narrowing. The magnitudes of changes in width were small at all but a few locations. At one of these locations, a couple of miles below Broadbent (subreach 7C), the channel was as wide or wider in 1939 than it is today in the most unstable portion of reach SFC-2 (i.e. subreach 7D). By 1992, the channel within subreach 7C had narrowed by as much as 50%, reflecting the river's ability to recover stability following disturbance.

Historic Changes: Comparisons of 1939 and 1997 Aerial Photos. Comparisons between recent and historic aerial photos are often used to evaluate changes or trends in stream channel and adjacent riparian conditions. For example, Florsheim and Williams (1996) examined eight sets of aerial photos taken of the Middle Fork to Broadbent reach (SFC-2) at varying intervals between 1939 and 1992. They concluded that over the 54-year period this section of river was (1) bordered primarily by a narrow strip of riparian vegetation and (2) experienced episodic bank migration that varied by location while averaging 0.3 feet/year across the entire reach. The level of channel migration reported was not particularly extreme even though shifts in channel position did occur at some locations, as previously discussed (see Figure 9).

We supplemented Florsheim and Williams' work by interpreting the oldest (1939 black/white images; 1:10,500-scale) and most recent aerial photos (1997 color images; 1:12,000-scale) available in order to assess changes in widths of the river's channel, riparian canopy, and riparian corridor within the study reaches. Our intent was to use the photos to develop a clearer understanding of how much change had or had not occurred within the study area during the period bracketed by the photos.

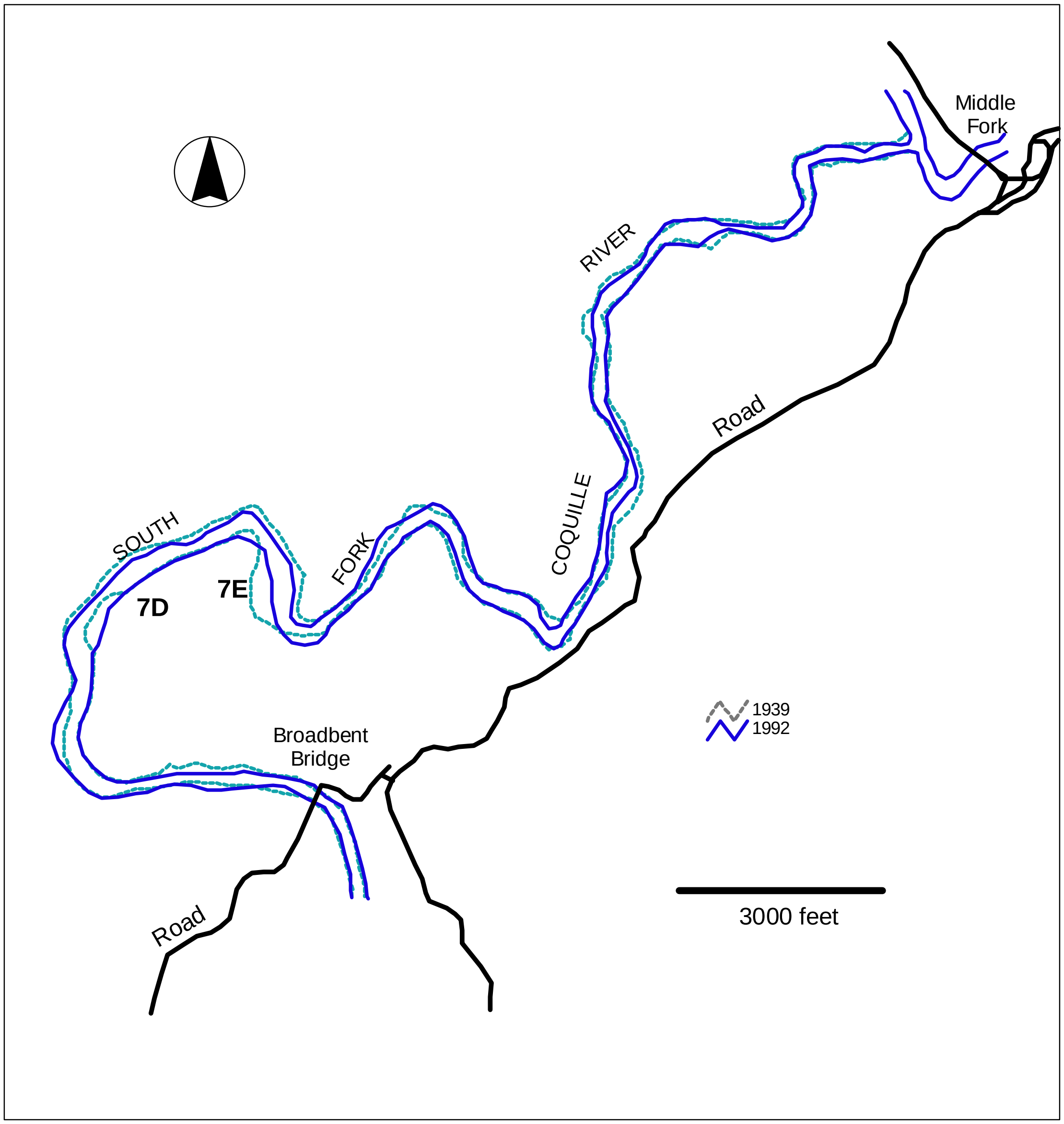

Figure 9. Shifts in channel position along the South Fork Coquille River between the Middle Fork and Broadbent, 1939-1992. Source: air photo interpretations by Florsheim and Williams (1996).

The photo-based evaluation was conducted by first making qualitative comparisons of the two photo sets to identify any gross-scale changes that were evident. We then established sample points (139 total) at constant 0.25-mile intervals along the river in the 1997 photos, carefully transfered these points to 1939 photos, scanned all photos into a computer, then used SigmaScan (Fox and Ulrich 1995) to measure and record the widths of interest for each station and year. Means and patterns of variation in conditions at the multiple stations within each study reach below Rowland (SFC-1 through SFC-5) were then compared across the two years. Good 1939 photo coverage of the reaches above Rowland was either incomplete (for SFC-6 and SFC-7) or non-existent (for SFC-8).

Qualitative comparisons. Two gross-scale patterns evident in the air photos seem worthy of note. First, most of the historic loss of riparian forests that Benner (1991) described for the lower river occurred prior to 1939. Second, gravel deposition was more extensive along most of the lower South Fork in the earlier (1939) photos than in the more recent (1997) ones, suggesting major inputs of sediment to the channel when the watershed was first developed. Much of the river channel was clearly incised in the 1939 photos, although whether the degree of incision was as great as in 1997 (or today) could not be discerned. It is possible that high levels of sediment delivered to the channel in early years partially counter-acted tendencies toward incision. It has been hypothesized that changes in watershed management that have reduced sediment inputs in the last couple of decades may have combined with commercial gravel mining that occurs in reaches SFC-3 through SFC-5 to allow additional channel incision along lower portions of the study area (Florsheim and Williams 1996). Our review of the air photos could neither confirm nor deny this chain of events.

Quantitative assessment. Measurements taken from the 1939 and 1997 air photos indicated variable changes in the widths of channel openings, riparian canopies, and riparian corridors along the five reaches of the lower South Fork that we assessed (Table 7; see Appendix J). The direction and magnitude of these changes varied among reaches and among sites within reaches, but several patterns were evident. Changes documented in each river reach downstream of Rowland (i.e., SFC-1 through SFC-5) are described below:

- *Reach SFC-1.* The mean width of channel openings increased while the riparian canopy tended to get narrower at the mainstem photo-points between the mouth and Middle Fork. Mean width of the riparian corridor changed little along the reach, suggesting that the reduction in channel opening may have resulted from increases in channel width, losses of large trees overhanging the channel, or both.

Table 7. Mean values for the widths of channel openings, the riparian canopy, and the riparian corridor at sample points within five reaches of the lower South Fork Coquille R., 1939-1997. Data were based on interpretations of air photos.

Reach	Year	Channel opening	Riparian canopy width	Corridor width
SFC-1	1939	107.6 (5.9)	80.7 (9.8)	269.0 (21.3)
(n=19)	1997	145.1 (9.7)**	64.0 (7.5)	273.1 (13.8)
SFC-2	1939	109.3 (15.3)	74.6 (9.1)	258.4 (17.8)
(n=20)	1997	144.8 (15.1)*	70.3 (10.2)	285.4 (21.4)*
SFC-3	1939	168.6 (24.2)	65.5 (9.7)	299.6 (33.1)
(n=21)	1997	139.8 (8.6)	90.0 (14.2)	319.8 (32.5)
SFC-4	1939	138.0 (10.5)	96.9 (14.8)	331.8 (25.8)
(n=14)	1997	128.9 (15.4)	78.4 (12.2)	285.7 (26.8)*
SFC-5	1939	183.8 (22.8)	129.4 (17.7)	442.6 (41.3)
(n=18)	1997	137.5 (6.2)*	98.1 (13.4)*	333.7 (25.9)*

* significantly different ($p<0.1$)
** very significantly different ($p<0.01$)

- *Reach SFC-2.* Channel opening and riparian corridor width increased while the mean width of the riparian canopy changed little along the South Fork between the Middle Fork and Broadbent between 1939 and 1997. These differences combine to reflect a substantial increase in average channel width during this period. Given that any overall increase in channel width here was not particularly dramatic between 1939 and 1992 (see Figure 9), this appears to reflect very recent morphological changes within the reach. Multiple sample points along this reach lost all of the trees on one of their banks.

- *Reach SFC-3***.** Changes were variable within the reach from Broadbent to Dement but tended toward narrower channel openings and wider riparian canopy widths. Multiple sample points along this reach had riparian canopies considerably wider in 1997 than any of the sample points had in 1939.

- *Reach SFC-4.* Between Dement and Gaylord, the South Fork experienced a significant reduction in the mean width of its riparian corridor between 1939 and 1997. Multiple sample points along the reach lost all of the trees on one of their banks during the period.

- *Reach SFC-5*. The reach between Gaylord and Rowland experienced significant reductions in channel openings between 1939 and 1997, partly reflecting strong channel narrowing and riparian encroachment at sites that had very wide openings in 1939. Contrasting with this trend, mean riparian canopy and corridor widths declined significantly during the period. Much of the riparian loss was caused by land-clearing activities that removed trees from the outer portion of formerly wide stands of trees.

Analytical Approximations of Stable Channel Geometry. Two study reaches, SFC-2 and SFC-3, appear to deviate substantially more from their historic or "potential" condition than do the other six reaches. Losses of sinuosity, channel down-cutting, riparian decline, and other changes have affected their stability. We took measurements from our planview maps of the circa 1870 and circa 1980 alignments of these two reaches as a basis for developing *very preliminary approximations* of the level of re-meandering that might be needed to re-establish natural channel stability. We also used channel geometry equations provided by Rosgen (1996; page 8-34) to calculate selected dimensions of the "potential" channel for each reach, largely for comparison to the information developed from measurements of the historical alignment.

Using direct measurements from historic channel alignments as indicators of natural stability, PWA used sine-generated curves to mathematically predict the increase in meander amplitude needed to return the river to its historic sinuosity (A. Collison, PWA, pers comm.). For the Middle Fork to Broadbent reach (SFC-2), the river would need to increase its meander amplitude by around 502 feet to re-establish the level of sinuosity assumed to be stable. For the Broadbent to Dement reach (SFC-3), the amplitude would need to increase by about 469 feet. This implies that unless the banks are stabilized through some combination of aggressive treatments with vegetation and strategic protection of most-vulnerable banks with bio-engineered toe protection, set-back allowances of these amounts may be required to permit the river to reach a natural state of equilibrium. These set-back distances would not be required everywhere, because maximum erosion would be expected to occur only on the apexes of meanders, and on the downstream ends of the meanders.

Equations and theory provided by Rosgen, plus field data from our representative channel segments, combine to suggest that idealized stable channels within these two reaches would have the following characteristics:

Reach	W/D ratio	Bankfull width	Meander length	Meander radius of curvature
SFC-2	12:1	166 ft	1660-2324 ft	415-498 ft
SFC-3	12:1	160 ft	1600-2240 ft	400-480 ft

Such channels would look substantially different than those found in the area circa 1870.

3.3.3. Implications of Our Level III Analyses With Regard to Improving Channel Stability

Within the pre-developed landscape, the lower South Fork had streamside forests dominated by large trees that overhung the river channel to a greater degree than most of the altered riparian community does today. It is clear that it also had a wood-affected channel with lower sediment transport and bank erosion rates. Wide corridors of riparian vegetation along the river apparently once transitioned from a conifer-dominated condition near what is now the National Forest boundary to hardwood communities containing few conifers along the lower study reaches. Removal or alteration of these streamside forests, changes in watershed conditions, and other factors have over time led to a simplified river system with reduced habitat quality and increased channel incision throughout most of the lower South Fork. These changes have contributed to reductions in channel stability that have been relatively minor upstream of Rowland (in reaches SFC-6 through SFC-8), greater below Rowland (in reaches SFC-1 through SFC-5), and particularly pronounced in some segments of the two study reaches between the Middle Fork and Dement (SFC-2 and SFC-3).

Along some segments of the South Fork below Rowland, and particularly below Dement, the once-extensive bottomland forest has been replaced by a narrow band of hardwoods or shrubs that often provides only limited resistance to toe erosion and lateral channel migration. Some segments of riverbank lack even this level of vegetative protection and consist of bare earth or grasses that may be grazed by livestock. Where narrow, sparse or negligible riparian buffers combine with the reduced geotechnical bank stability that has been caused by historic channel incision and associated increases in bank height, a situation is created where the risk of rapid bank erosion is high. In these high-risk situations, both the vulnerability of riverbanks to erosion and the magnitude of the erosive forces acting within the channel during floods have been increased. Natural channel migration or subtle shifts in channel alignment caused by localized "bank protection" measures within these high-risk areas can cause the river to erode bank toes, oversteepen banks, remove remaining vegetation, and erode floodplain soils at a rate unaffected by the resistance provided historically by a bottomland forest.

Given what is known about the lower South Fork, it seems clear that efforts to improve channel stability in vulnerable areas will be ineffective unless river down-cutting has been stopped or reversed and that the restorative actions taken by landowners are first planned collaboratively at a sub-reach to reach scale. Areas of high riparian integrity need to be maintained or expanded, and riparian setback distances need to be increased where possible. Stabilization efforts will require that raw banks be at (or re-contoured to) geotechnically stable angles for their heights and that riparian vegetation be restored to help resist lateral erosion. Successful vegetative plantings on the lower to mid-elevation surfaces of banks will help maintain stable bank angles. These plantings are likely to rely heavily on the ability of willows to colonize disturbed sites and will often need to be quite intensive. Cautiously applied bioengineering approaches that include the use of rock may be needed to help stabilize bank toes in some instances, but localized bank treatments that are not part of a coordinated sub-reach to reach-scale restoration effort should be avoided. Treatments implemented without such context appear to have contributed to channel instability problems seen in some of the least stable areas along the lower river.

4. SHADOW MODELING

The CWA asked that stream shading within the study area be evaluated using the SHADOW model developed by the U.S. Forest Service (USFS 1993). SHADOW is a spreadsheet model that runs under Lotus123 and uses trigonometric relationships combined with data on sun angle, latitude, stream aspect, channel form, and riparian conditions to estimate the degree to which a stream is shaded from incoming solar radiation. The model can be used to estimate existing levels of stream shading and to predict future levels of shading that would result from changes in riparian conditions and/or channel form. SHADOW outputs thus provide an opportunity to (1) examine spatial patterns of shading along a stream or within a drainage network, and (2) identify the magnitude of potential shade improvements that could be achieved if conditions were restored to their potential along segments of stream altered by past activities. Both uses of the model were the intent of the CWA when it requested that the SHADOW model be applied to the study area. Model outputs will give the CWA a useful tool for identifying where riparian projects will help lower stream temperatures and thus improve water quality conditions in the South Fork Coquille River watershed.

4.1. DATA ACQUIRED FOR EVALUATIONS OF STREAM SHADING

A combination of field and office-based methods was used to acquire data on 16 parameters relevant to an evaluation of stream shade levels along the 154 channel segments delineated within the study area (Table 8). Information on each parameter was compiled for each channel segment and subsequently incorporated into an Excel spreadsheet. Data on 12 of the parameters were required as segment-specific inputs for SHADOW (USFS 1993). These data could be manipulated and copied within Excel then pasted into appropriate columns within the SHADOW spreadsheet in order to perform a specific analysis. Data on the other four (supplemental) parameters were useful in structuring SHADOW analyses or were of interest to the CWA for other reasons related to its riparian restoration program.

Table 8. Parameters and data types (assigned [A], field measured [F], map-based [M], interpreted from aerial photos [Ph], and predicted [Pr]) acquired for evaluating stream shade conditions along the lower South Fork Coquille River and selected tributaries.

Parameter	Model input required by SHADOW?	Data types for the South Fork	Data types for tributaries
Reach/segment identification code	yes	A	A
Selected (Y/N) for analysis	yes	A	A
Stream orientation (aspect of –90 to 0 to +90)	yes	M	M
East/West/Both (streambank designation)	yes	Ph, M	Ph, M
Channel length (feet)	yes	M	M
Active channel width (feet)	yes	F	Pr
Low flow stream width (feet)	yes	F	Pr
Percent tree overhang (decimal percent)	yes	F	Ph
Tree height (feet)	yes	F	Ph
Tree to channel distance (feet)	yes	F	Pr
Tree to channel slope (decimal percent)	yes	F	Pr
Shade density (decimal percent)	yes	F	Ph
Riparian vegetation type	no	F	Ph
Structures in riparian corridor (decimal percent)	no	Ph	Ph
Landuse type	no	M, Ph	M, Ph
Width of riparian management zone (feet)	no	M, Ph	M, Ph

Field measurements were given very strong emphasis in assembling the shade-related data for analyses of conditions along the mainstem South Fork, with values for measured parameters obtained at each of the 3-4 equally spaced channel cross-sections examined within each study segment as part of the geomorphic analysis . There were two primary reasons for this emphasis on field data. First, field measured data are more reliable than those derived from air photo interpretations or other office-based methods. We found early in the study that a high and variable level of channel incision made it difficult to impossible to generate reliable office-based estimates of parameters like tree height along many segments of the mainstem river. Second, the entire mainstem could be (and was) easily reached via kayak or on foot from multiple strategic private access points, allowing concurrent collection of extensive riparian and stream channel data that could be used for our analyses both of stream shading and (as described in Section 3.2.1) of channel morphology.

Data on shade-related parameters for stream reaches in the tributary watersheds (Dement, Yellow, and Hayes Creek) were derived primarily from interpretations of 1:12,000-scale color air photos taken during Spring 1997, predictive relationships developed from field measurements taken at a limited number of locations, and other office-based methods. Photo-interpreted data for these reaches were checked at a subsample of five intensively measured reaches in the Dement Creek watershed that were evaluated using the same transect-based methods applied along the mainstem South Fork, and at several additional reaches examined at lower intensity (Appendix Table J1). Field evaluations helped to verify or calibrate photo-based data developed for the tributaries but did not provide the high level of confidence in parameter values that was obtained for the mainstem channel segments. *Our ability to acquire additional field data to validate or calibrate the tributary data was limited by access to private lands and budgetary constraints.*

4.1.1. SHADOW Inputs

Descriptions of the data compiled for each input parameter needed to run the SHADOW model are given below. Actual parameter values incorporated into our database and used to run the model are provided in Appendix Tables J2-J5.

Reach/Segment Identification Code. A total of 154 stream segments were evaluated using the SHADOW model. These were the same segments examined during the geomorphic assessment of streams in the study area and were delineated on the basis of changes in one or more of the following: Rosgen channel type, stream orientation, riparian conditions, and landuse type. Each stream segment was identified by a unique alpha-numeric code so that data on channel and riparian conditions along the segment could be incorporated into a GIS (ArcView) and georeferenced to digital maps of the study area. The codes used were the same as those assigned during the geomorphic assessment described earlier in this report.

Selected (Y/N) for Analysis. Each channel segment was selected ([Y]es) when shade conditions along the stream or stream system (watershed) of which the segment was a part were evaluated. Segments could be excluded ([N]o) from analyses when appropriate.

Stream Orientation (-90^{o} to 0^{o} to +90^{o}). Stream orientation was measured as described in the SHADOW user's manual (USFS1993), using 7.5-minute topographic maps and a protractor to determine the rotational angle (to the nearest 5^{o}) between due North and the actual alignment of the channel segment.

East/West/Both (Streambank Designation). The SHADOW database was structured to provide one record (a full set of parameter values) for each stream segment unless streambank conditions differed substantially between the two banks along a given segment. Where segments were represented by one record, the streambank designation was assigned a value of "B" to indicate that conditions along both banks were similar. Where conditions were substantially different along the two streambanks bordering a channel segment, two records with identical channel parameters but differing riparian conditions were incorporated into the database. Such cases accounted for 55 of the 154 channel segments in the study area, with each record identified as being for the East ("E") or West ("W") streambank as defined by rules given in the SHADOW user's manual (USFS 1993).

Channel Length (Feet). The length of each channel segment was measured from digital versions of 7.5-minute topographic maps. Segments ranged in length from 800 to 8350 feet along the mainstem South Fork and from 530 to 5135 feet on streams in the three tributary watersheds.

Active Channel Width (Feet). Active (bankfull) width was field measured within each mainstem channel segment by project staff, field measured in 10 dispersed tributary reaches by project staff or during recent ODFW aquatic surveys, and predicted for the remaining tributary reaches. Channel widths entered into the SHADOW database for segments of the mainstem South Fork were each the average of measured values obtained at 3-4 evenly spaced cross-sections in a given segment. The pattern of variation in these widths along the length of the lower South Fork and among the mainstem channel segments was shown earlier, in Section 3.3.2 of this report (see Figure 6). The mean active channel width of the mainstem segments ranged from 84 to 223 feet and at times differed substantially between adjacent segments.

As indicated, channel widths for tributary reaches within the study area were either measured in the field or predicted. Predicted values were derived through the use of a relationship developed by regressing channel width versus distance from headwater (per 7.5 minute USGS topographic maps) for the 10 tributary reaches that were measured (Figure 10). For each unmeasured reach, active channel width was predicted as 4.8942 + (0.0011)(distance [in feet] from the tributary's headwater). Active channel widths incorporated into the SHADOW database for the 87 tributary reaches varied from 6 to 49 feet.

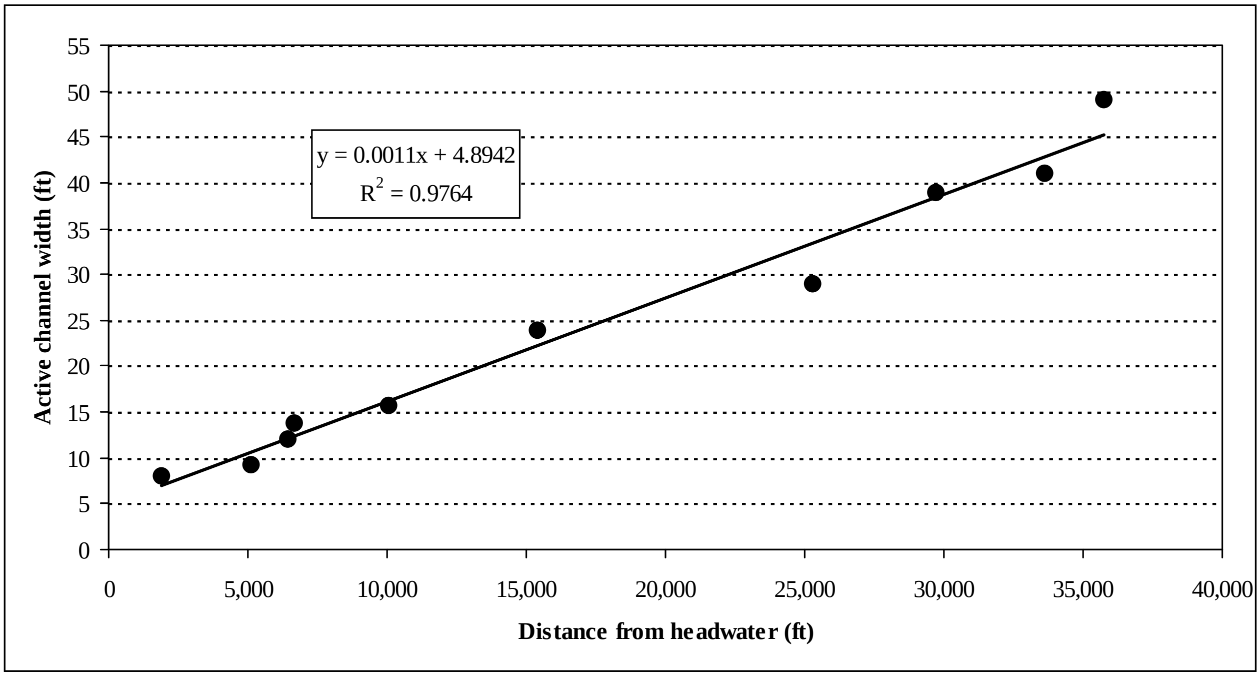

***Figure 10. Active (bankfull) channel width versus distance from headwater for 10 channel segments on tributaries to the lower South Fork Coquille River, Oregon*.**

Low-flow Stream Width (Feet). Low-flow widths were measured by project staff within each of the channel segments delineated along the mainstem South Fork, measured in seven tributary reaches for which information on active channel width was also available, and estimated for the remaining tributary reaches. Low-flow widths entered into the SHADOW database for segments of the South Fork were the means of values measured during September 2001 at the same 3-4 evenly spaced cross-sections per segment that were measured for active channel width. The pattern of variation in low flow width along the length of the lower South Fork and among the mainstem channel segments is shown in Figure 11. The mean low-flow width of the segments ranged from 30 to 197 feet and in multiple instances differed substantially between adjacent segments.

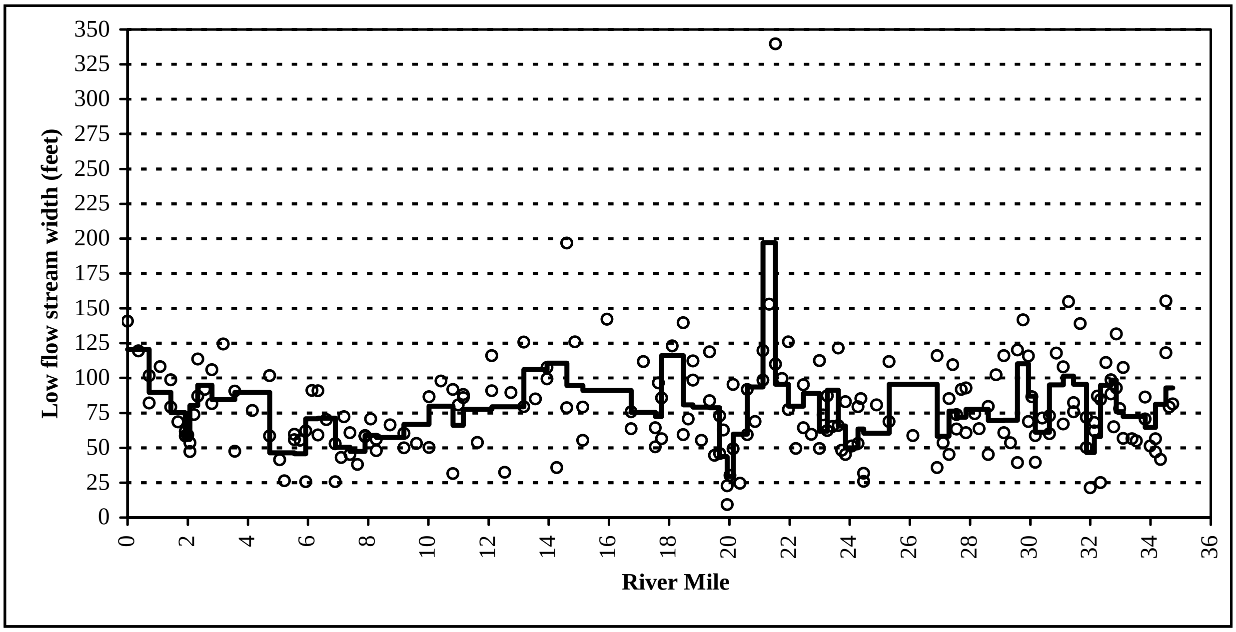

Figure 11. Low-flow width versus River Mile, lower South Fork Coquille River, Oregon, September 2001. Open circles represent individual width measurements and the bold black line depicts variation in mean width among 67 channel segments delineated during the study.

Low-flow widths entered into the SHADOW database for the tributary reaches were either measured or predicted and ranged from 0.0 to 19.0 feet. Where measurement data on low-flow width were lacking, the predicted value for a given reach was 14.7% of the measured or predicted active channel width for that reach. This was the average value found at the tributary reaches for which both low-flow width and active channel width measurements were available (mean= 14.7%; S.E.= 6.9%; n=7).

Percent Tree Overhang (Decimal Percent). The percent of active channel width and of low-flow stream width overhung by riparian vegetation were measured at the multiple cross-sections examined within each study segment of the mainstem South Fork during September 2001. Segment-specific means for percent vegetative overhang varied considerably along the lower river (Figure 12), ranging from 0 to 23% (average = 9%) for the channel and 0 to 19% (average = 3%) for the wetted stream. The values for vegetation overhanging the wetted stream were incorporated into the SHADOW database as "Percent tree overhang" because they were more strongly related to levels of stream shading observed in the field.

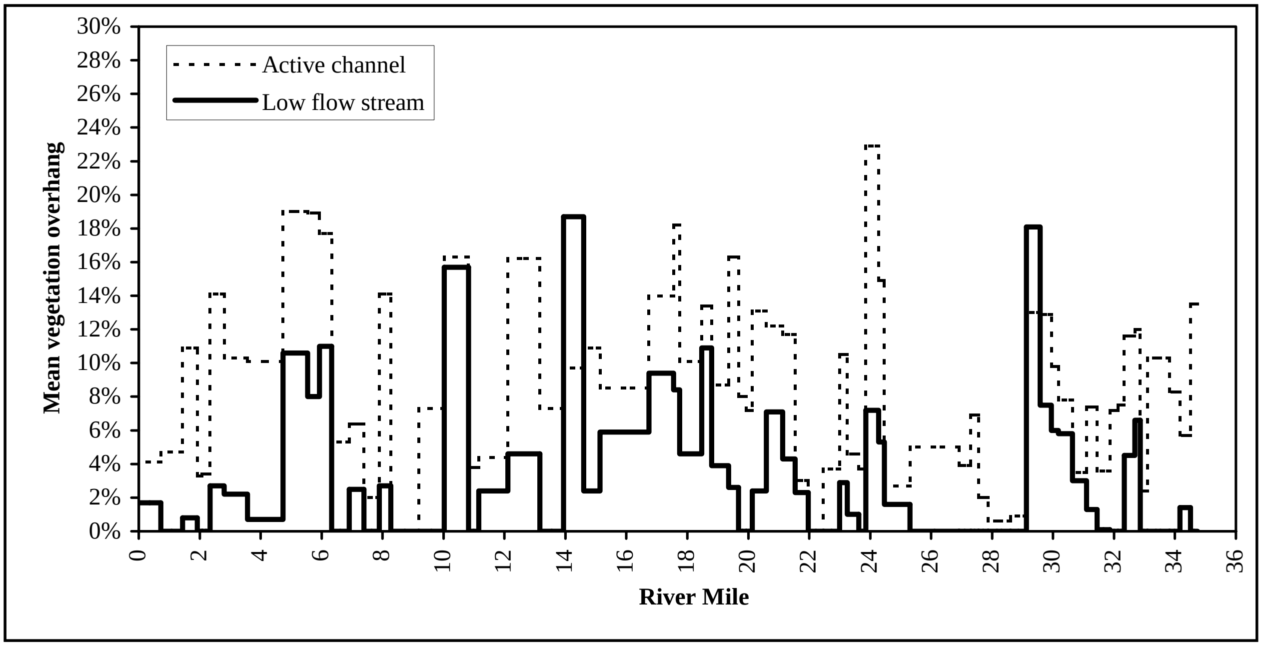

Figure 12. Longitudinal variation in the percentage of active channel width and of low-flow (wetted) stream width overhung by riparian vegetation, lower South Fork Coquille River, September 2001. Values shown are means for each of 67 study segments of the river.

Estimates of percent tree overhang for each tributary reach within the study area were developed by interpreting air photos and checked at five calibration reaches that were examined using the same transect-based field techniques used along the mainstem South Fork. Photo-interpreted values for percent tree overhang varied from 15 to 95% among the tributary reaches, averaged 82%, and differed little (mean = +2%) when checked against the means of field-measured values obtained within the calibration reaches. Photo-interpreted values were entered directly into the SHADOW database unless a particular tributary reach had been measured, in which case the mean field-measured value for percent overhang was entered.

Tree Height (Feet). Existing condition values used for this SHADOW parameter were based on direct measurements of the height of vegetation along the mainstem South Fork and on air photo interpretations plus limited field-checks of conditions for stream reaches in the tributary watersheds. On the South Fork, we measured the heights of the primary shade-producing vegetation at the bank ends of the multiple cross-sections examined within each study segment. These heights varied both within and among segments (Figure 13), with segment-specific mean heights ranging from 19 to 94 feet. A high level of variation found within individual mainstem segments often reflected patterns of riparian disturbance and caused us to use the 75th percentile height measured along each segment of channel or riverbank as a best approximation of the dominant "tree height". This approach was used so that unusually tall or short vegetation would not skew estimates of the height of dominant vegetation and allowed us to use the "shade density" parameter in SHADOW to account for measured variability in the height of shade-producing vegetation bordering individual channel segments (described later).

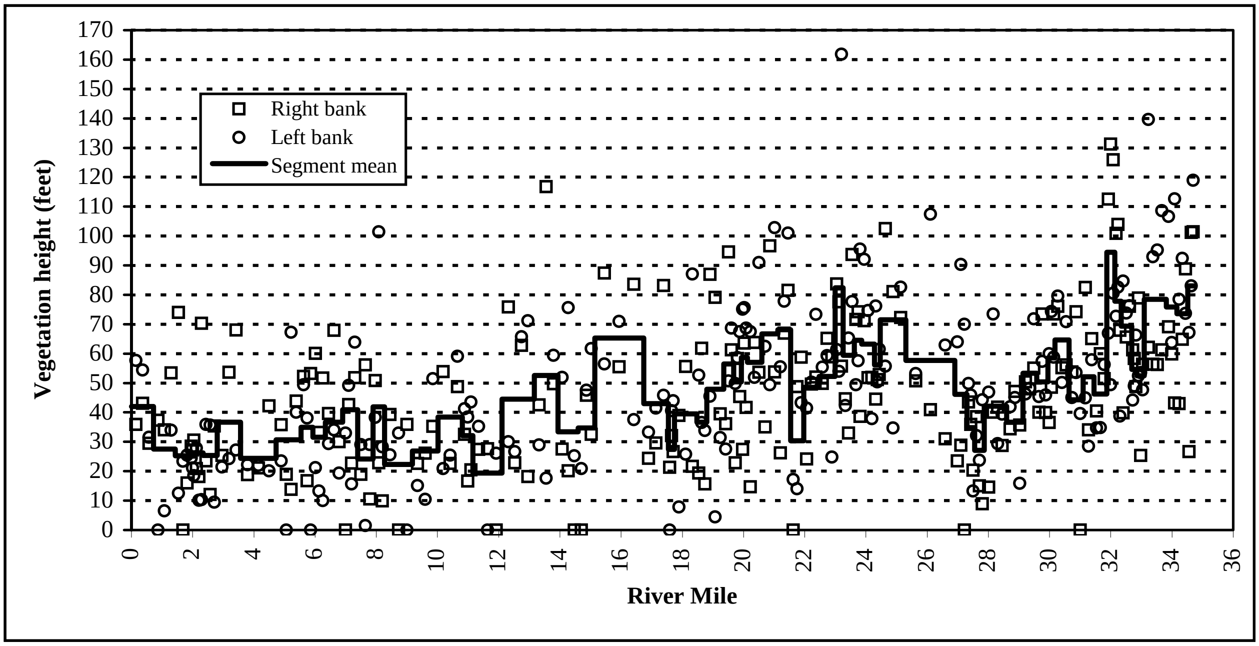

Figure 13. Longitudinal variation in the height of dominant, shade-producing riparian vegetation, lower South Fork Coquille River, September 2001. The bold line gives mean values for each of 67 study segments of the river.

The height of the dominant shade-producing vegetation bordering each of the 87 study reaches in tributary watersheds was estimated from the 1997 air photos and measured in the field at 11 (13%) of these reaches. Photo-based estimates of tree height were very similar to field values for all 5 measured reaches that had low (<2%) gradients (mean error = +3%). Photo-based estimates were therefore incorporated directly into the SHADOW database, without adjustment, for each low-gradient reach lacking measurement data. Photo-based tree height estimates for the remaining measured reaches, all of which had channel gradients >2%, were biased low. For this reason, photo-based estimates for steeper (i.e., $\geq$2%) channel segments that lacked measurement data were incorporated into the database after applying a regression-based correction derived from our data for the steeper measured reaches: tree height = 1.275 x estimate + 0.107 (r^2=0.87). Measured tree heights were used in the SHADOW database whenever available.

Tree to Channel Distance (Feet). Channel offsets for primary shade-producing vegetation were measured at the bank ends of multiple equally spaced cross-sectional transects within each study segment of the mainstem South Fork and within each of the five intensively measured tributary reaches in the Dement Creek watershed. Mean values of these measured "tree to channel" distances were entered directly into the SHADOW database. Mean offset distances measured within study segments of the South Fork ranged from 8 to 52 feet (Figure 14), while those for the measured tributary reaches varied from 3 to 13 feet. Lacking better data, the following tree to channel distances were assumed for unmeasured tributary reaches: 4 feet for first-order channels, 5 feet for second-order channels, and 10 feet for third order channels. These values were based on those found at the measured tributary reaches and fall within ranges suggested as appropriate in the user's manual for the SHADOW model (USFS 1993).

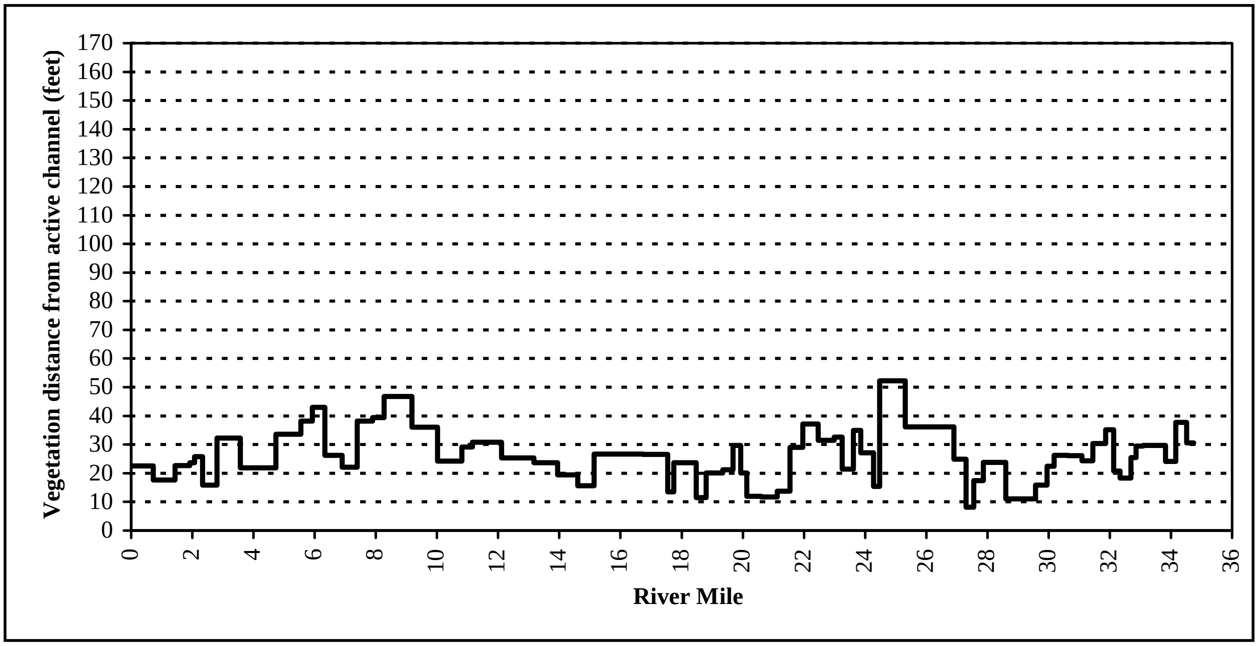

Figure 14. Longitudinal variation in the distance between the primary shade-producing vegetation and the active (bankfull) channel, lower South Fork Coquille River, September 2001. Values shown are means for each of 67 study segments of the river.

Tree to Channel Slope (Decimal Percent). Mean tree to channel slope was calculated from field measurements taken at the multiple cross-sections examined within each study segment on the mainstem and within each of the five intensively evaluated reaches in the Dement Creek watershed. Each calculated slope positioned shade-producing vegetation the appropriate height above the low flow water surface (Figure 15).

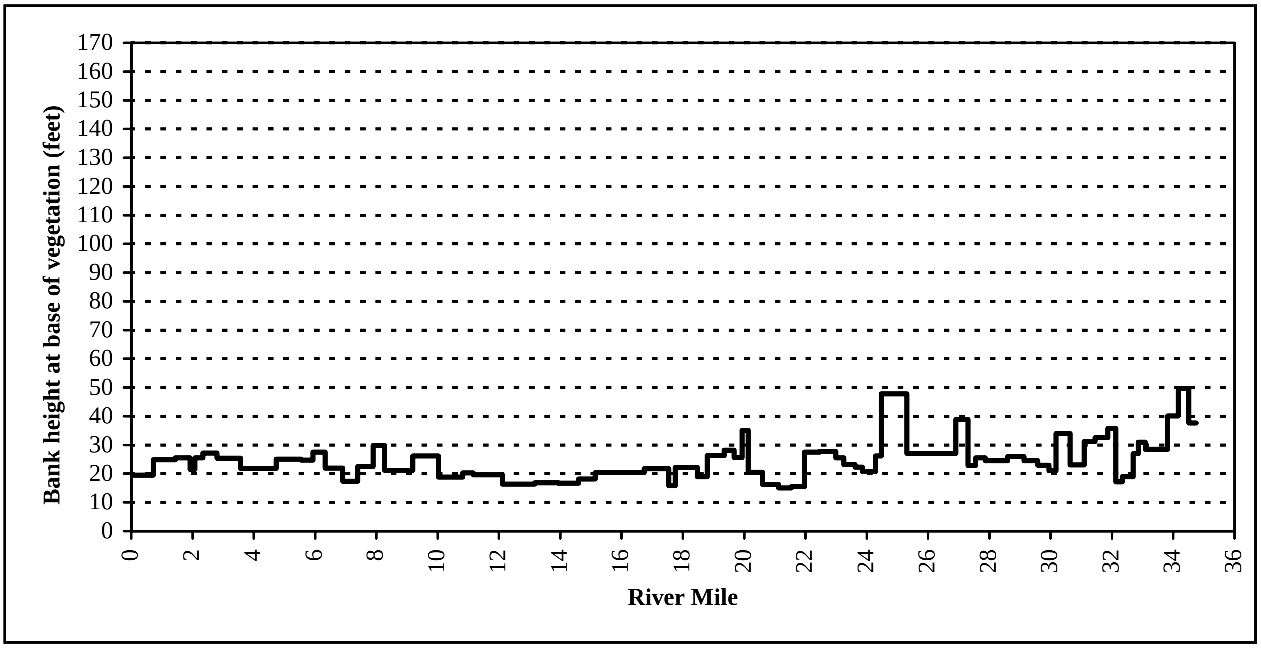

Figure 15. Longitudinal variation in bank height (relative to the low-flow water surface) at the base of primary shade-producing vegetation, lower South Fork Coquille River, September 2001. Values shown are means for each of 67 study segments of the river.

The following values for tree-to-channel slope were assigned to unmeasured tributary reaches: 0.65 for 1st order channels, 0.54 for second-order channels, and 0.43 for third-order channels. These were the means of tree-to-channel slope values that Follansbee (2002) found within the nearby North Fork Coquille watershed along channels in what he called “steep canyon”, “medium canyon”, and “small valley” streams, respectively. The values were adequate for our modeling purposes because (1) they were not substantially different from those actually found along the tributary reaches that were measured and (2) this parameter had a relatively negligible effect on SHADOW outputs given the close proximity of riparian trees to tributary channels (see above).

Shade Density (Decimal Percent). Shade density values incorporated into the SHADOW existing conditions database were either based on measurements taken at multiple cross-sectional transects within a channel segment or interpreted from air photos. Values for each segment of the lower South Fork and for the five intensively measured reaches in the Dement Creek watershed were calculated from field data as follows:

1. All measured vegetation heights for the streambank(s) were pooled.
2. Vegetation heights exceeding the 75th percentile value (i.e., potential tall outliers) for the streambank(s) were truncated to the 75th percentile height.
3. Each measured (or truncated) height was divided by the 75th percentile height.
4. The average of the values obtained in step 3 (above) was multiplied by an estimate of riparian canopy density (in decimal percent). A canopy density of 0.95, representative of the means of densiometer readings we obtained beneath hardwoods (94.9; n=46; SE=0.5), conifers (93.8; n=16; SE=0.7), mixed tree stands (94.7; n=9; SE=8), and shrubs (95.3; n=14; SE=0.5) along the lower South Fork, was used for all mainstem channel segments. Canopy densities measured on-site with a densiometer were used for each of the five measured tributary reaches.

Photo-based estimates of shade density for the measured reaches in the Dement Creek watershed were within about 10 percent or less of the values calculated from field measurements, with a slight (-3 percent) bias toward underestimating shade density. The small number of measured reaches and limited degree of apparent bias led to a decision to use unadjusted photo-based estimates for this parameter for all unmeasured tributary reaches within the study area.

4.1.2. Other Shade-related Parameters Included in the Database

<u>Riparian Vegetation Type</u>. Predominant riparian vegetation along channel segments was classified into types on the basis of field observations at transects or through air photo interpretation. Vegetation types included were those suggested by the OWEB watershed assessment manual (Watershed Solutions 1999): grass/forbs [G], shrubs [S], hardwood trees [H], mixed tree species [M], and conifer trees [C].

<u>Structures in Riparian Corridor</u>. The areal percent of the riparian corridor within 100 feet of the active stream channel that was occupied by roads, buildings, or other artificial structures was estimated from the 1997 air photos.

Landuse Type. Landuse along each of the 154 channel segments within the study area was classified as forestry (For) or agriculture/rural residential (Ag/RR). Classification was based on a combination of digital maps of zoned landuse and air photo interpretations. Actual landuse was not always consistent with zoned use. Classified use defaulted to zoned use unless actual use was consistently and dramatically different than zoned use.

Width of Riparian Management Zone. Widths of riparian management zones along the study segments were 50 feet on each side of stream channels within agricultural/rural residential lands and varied from 0 and 100 feet within forest lands.

4.2. MODEL CALIBRATION

Initial SHADOW output was compared to shade levels we actually measured within a sample of 10 (15%) of the 67 mainstem channel segments [sub-reaches] and 5 (6%) of the 87 tributary segments [reaches] within the study area. This was done to check for potential bias in raw model output and to develop regression-based calibration equations for adjusting this output for any bias present. The true shade level of each sampled channel segments was measured using a Solar Pathfinder at multiple (3-6) transects spaced at even intervals along the length of the segment. True shade for a channel segment was calculated as the mean of the Pathfinder values recorded at all measurement points and reflected an averaging of July and August values read from the Solar Pathfinder instrument at each point. July and August values were used because SHADOW predicts shade level for August 1, a date on which the sun's angle is intermediate to typical July and typical August conditions. The number of shade transects measured within a given channel segment reflected the degree of variability in riparian conditions along the segment.

The calibration effort showed that our initial SHADOW modeling provided predictions of stream shade levels that were biased toward a slight (<2 percent) over-estimation of the shade actually measured in the sampled channel segments (see Appendix Table J1). Regression-based equations developed to adjust (calibrate) raw output from the SHADOW model to account for small apparent biases in our initial shade estimates are given in Figures 16 and 17. Figure 16 gives the equation we used to adjust raw SHADOW-based estimates of percent shade for sub-reaches of the mainstem and shows how well it fits our calibration data for the 10 mainstem sub-reaches sampled. Figure 17 provides the equation used to adjust raw model-based estimates of percent shade for reaches in the tributary watersheds and indicates how well it fits our calibration data for the 5 tributary reaches sampled.

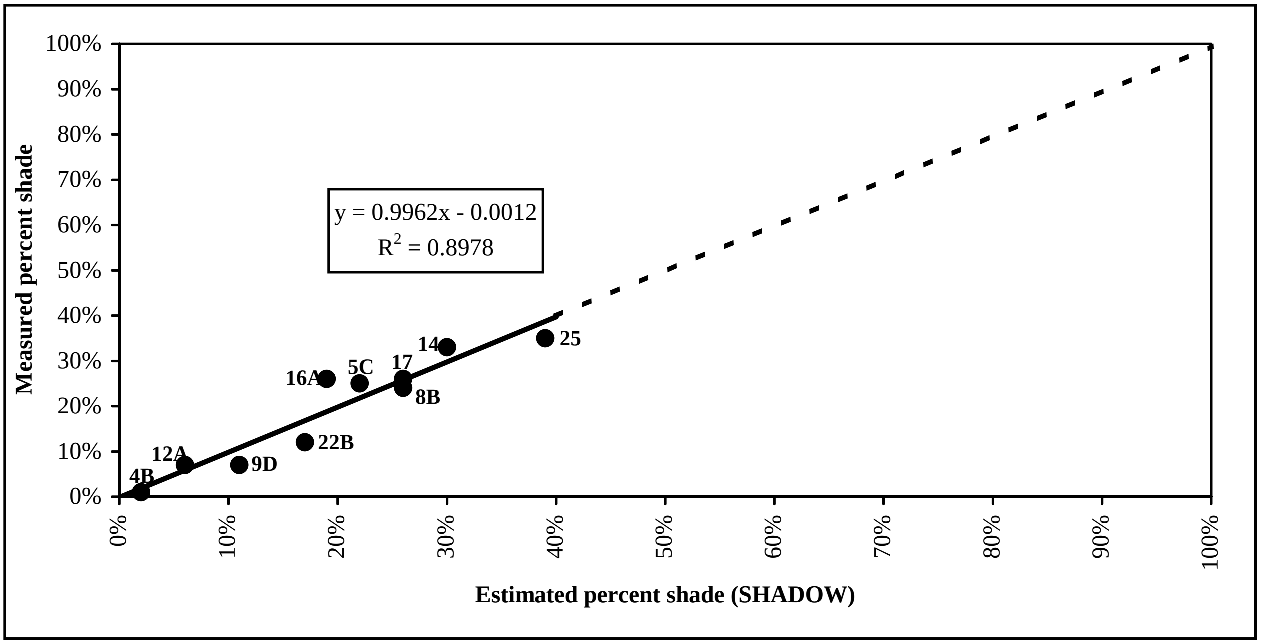

Figure 16. Unadjusted SHADOW (model) estimates of percent shade versus measured values for 10 sub-reaches of the lower South Fork Coquille R., Summer 2001.

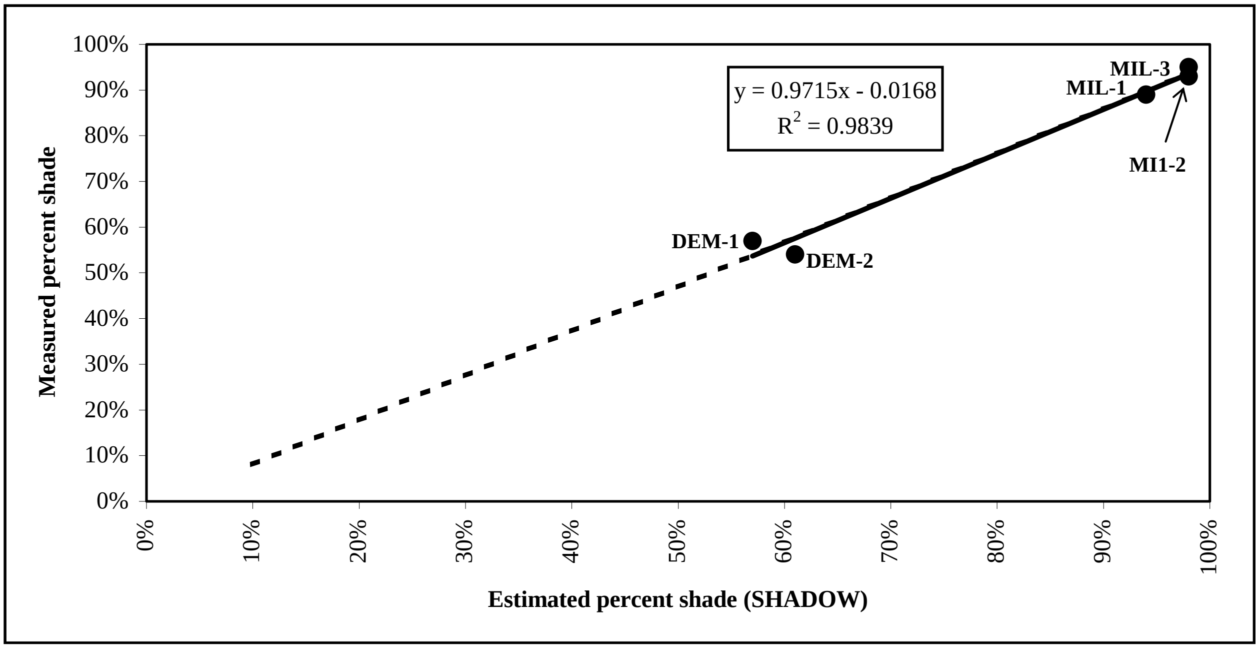

Figure 17. Unadjusted SHADOW (model) estimates of percent shade versus measured values for five reaches of tributaries to the lower South Fork Coquille R., Summer 2001.

4.3. MODELING SCENARIOS

4.3.1. Assessment of Existing and Potential Levels of Stream Shade

We ran SHADOW to model existing conditions and approximations of site potential conditions for the study area's 154 channel segments in order to assess patterns in current levels of stream shading as well as opportunities to improve shade conditions. The existing conditions modeled were those outlined earlier, in Section 4.1. Site potential conditions used in our modeling are described below, in Section 4.3.2.

4.3.2. Assumptions Made When Modeling Potential Shade

We kept the number and complexity of assumptions made to model potential shade to a minimum. This seemed appropriate given (1) uncertainties about future channel changes that may (or may not) occur along the mainstem South Fork and (2) that additional model runs with differing sets of assumptions may be made by CWA staff or associates.

Mainstem South Fork. For the mainstem, we modeled "potential" conditions by assuming only two types of changes to the inputs used to model the current situation. First, *we assumed that mean tree-to-channel distance would be reduced to 25 feet upriver from Dement and to 30 feet downriver from Dement on those banks where the distance currently exceeds these values*. This adjustment helped account for potential recovery from the disturbed riparian conditions found along much of the river and brought these tree-to-channel distances down to approximately the median values we measured for trees in streamside corridors above or below Dement during 2001. Tree-to-channel distances were assumed to remain the same as at present along riverbanks where the distances are already smaller than the values given above or in a few instances where steep talus slides adjacent to the river above Dement impede trees from encroaching upon the channel.

The second type of change we assumed in modeling "potential" shade conditions along the South Fork related to the types (and thus sizes) of stands of trees that could be growing along the various sub-reaches. We based our assumptions regarding these potential trees on field observations, riparian data collected during field surveys (see Figure 18), and results of an assessment of site potential vegetation that Follansbee (2002) conducted in streamside zones within the nearby North Fork Coquille River watershed. With the exception of the river reach surrounding Powers (SFC-7), riparian areas along the lower South Fork between the National Forest boundary and Rowland (i.e., in reaches SFC-6 and SFC-8) appear to have the potential for supporting mature stands of conifers or mixed tree stands strongly dominated by conifers. The Powers reach itself supports predominantly mixed tree stands strongly dominated by hardwoods, as does the river reach between Rowland and Gaylord (SFC-5). We consider mature stands of trees with something similar to the current balance of hardwoods and conifers to represent site potential vegetation along these two reaches. Riparian areas bordering the four study reaches of the South Fork below Gaylord (SFC-1 through SFC-4) are dominated by stands of hardwoods with very few conifers, wherever trees are present. Historical records (Benner 1991) combine with existing riparian communities in relatively least-disturbed areas suggest that these lower-most four reaches have the potential to support mature stands of mixed hardwoods that include Oregon ash, big-leaf maple, Oregon myrtle, red alder and pockets of black cottonwood.

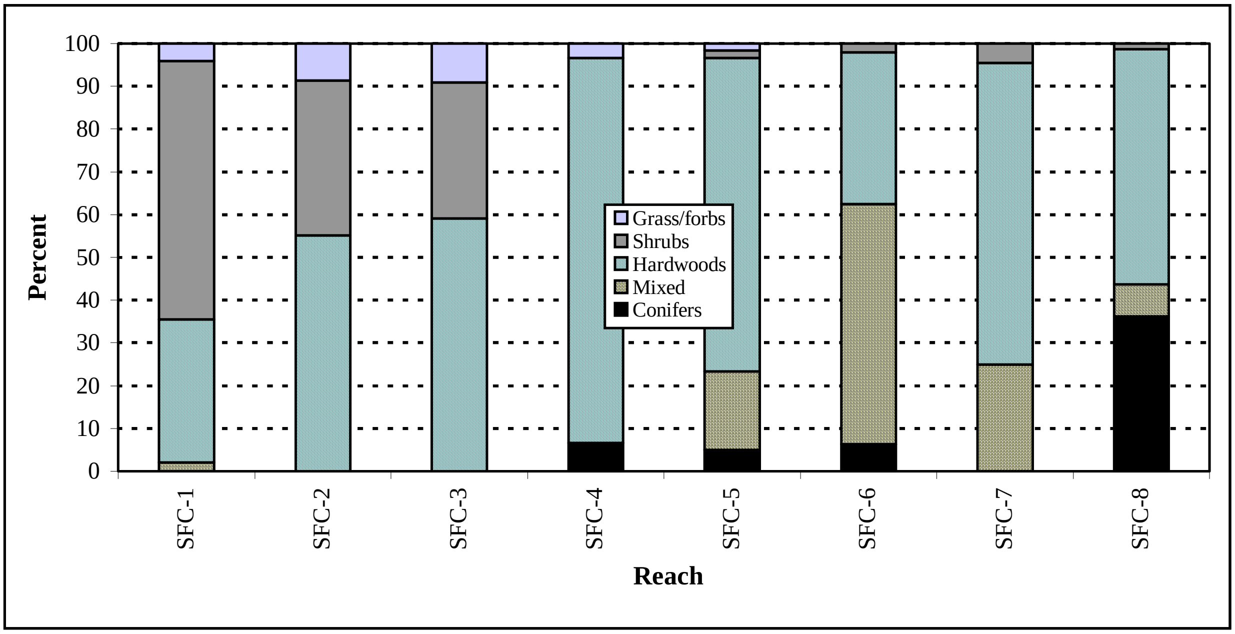

Figure 18. Percent of transect sites dominated by each of five classes of riparian vegetation, by reach, lower South Fork Coquille R., Summer 2001. See Appendix Table J6 for supporting data.

When using SHADOW to predict potential shade, we assigned specific tree heights and shade densities for the segments of the South Fork considered likely to support each of the differing types of potential communities identified (hardwoods, mixed predominantly hardwoods, and conifer-dominated). The specific heights and densities used are summarized below, along with the rationales behind their selection:

Potential community	Tree height (ft)	Shade density	Rationale
Hardwoods	105 feet	90%	Same potential height as assigned to similar communities in large valley settings on the N.Fk. Coquille R. by Follansbee (2002). Shade densities of about 90% were found in a few mature hardwood communities along the lower South Fork during 2001.
Mixed pred. hardwoods	110 feet	90%	Approx. maximum height of this community measured during 2001. Same height and density as Follansbee (2002) assigned to similar communities in the N.Fk. Coquille R. watershed.
Conifer-dominated	150 feet	90%	The combination of height and shade density was intended to represented a mature (but not old-growth) conifer community intermediate between pure stands of the 180-foot site potential conifers and 120-foot site potential hardwoods that ODEQ (2000) estimated for areas above the National Forest boundary. This seemed reasonable given the managed nature of private riparian areas along the lower South Fork to which this community was applied.

Tributaries. Percent tree overhang, tree height, and shade density were the only three input parameters adjusted from existing conditions when modeling potential shade for the study reaches in the Dement, Yellow, and Hayes Creek watersheds. Percent tree overhang was adjusted upward from existing conditions to 80% (when lower) along F or C-type reaches and to 90% (when lower) along reaches assigned other Rosgen types, based on some of the better conditions we observed along tributaries in the field. Mixed riparian stands of trees dominated by mature, near-stream hardwoods (110 feet trees and 90% shade density) with potentially larger trees farther from the stream were taken to represent site potential for all but one stream reach in the three watersheds. The tree height and shade density values assumed for this potential community were similar to values measured for dominant, shade-producing vegetation at the best-shaded tributary sites we examined in 2001. For a one reach on Yellow Creek, a mature hardwood stand with 105 foot trees and 90% shade density was assumed to represent site potential because the stream channel was in a valley floor setting analogous to that of segments of the mainstem South Fork given similar site potential values.

4.4 MODEL OUTPUT

Calibrated model output for the existing condition and potential condition scenarios was incorporated into databases (see Appendix Tables J7 and J8), summarized, and mapped using ArcView. Digital databases and ArcView files that can be used to review, supplement, and re-map model results are on file at the offices of the CWA in Coquille, Oregon.

Results of our SHADOW modeling reflect that both existing and potential levels of stream shading vary considerably within the study area. For the mainstem South Fork, where both existing and potential shade levels were generally lower than those of the tributary streams, our model-based estimates ranged from 0 to 40% for existing shade and from 10% to 61% for potential shade (Figure 19). Estimates of the scope for improving shade conditions within individual modeled segments of the mainstem varied between 9% and 39%.

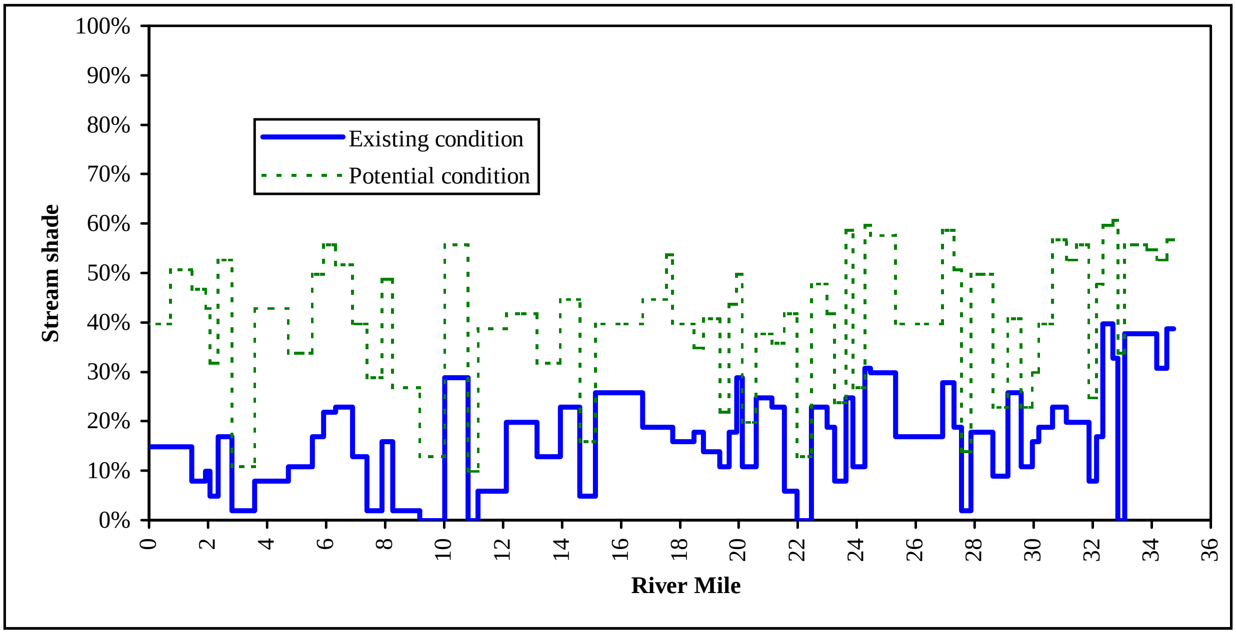

Figure 19. Estimated levels of existing and potential stream shade, versus River Mile, for the lower South Fork Coquille River, Oregon.

Differences between shade levels estimated for the lower South Fork mainstem and those estimated for the tributaries were substantial (Table 9). Existing levels estimated for segments of the mainstem averaged 16%, far below estimated watershed-scale averages of 83% to 87% shade for the 3 tributary systems evaluated. This difference reflected both lower potential shade and what were typically greater levels of riparian disturbance along the mainstem. Our model-based estimates of potential shade averaged 40% across the full length of the lower mainstem, less than half the watershed-scale averages of 93% to 94% we estimate for the tributary systems. Differences between existing and potential shade averaged 24% along the mainstem, more than twice the 6 to 10% average differences found the tributary watersheds.

Table 9. Mean estimates of existing and potential stream shade, plus scopes for improvement, along the lower South Fork Coquille River and in selected tributary watersheds, 2001. Values given for each stream/system and landuse category are length-weighted means of calibrated estimates for multiple channel segments modeled using SHADOW.

Stream/system	Landuse types	Existing shade	Potential shade	Scope for improvement
lower S. Fk. Coquille R.	Forest	27%	45%	18%
(mainstem only)	Ag/RR	15%	39%	24%
	All	**16%**	**40%**	**24%**
Dement Cr. and tributaries	Forest	85%	93%	8%
	Ag/RR	76%	90%	14%
	All	**83%**	**93%**	**10%**
Yellow Cr. and tributaries	Forest	91%	94%	3%
	Ag/RR	80%	92%	12%
	All	**87%**	**93%**	**6%**
Hayes Cr. and tributaries	Forest	84%	93%	9%
	Ag/RR	85%	92%	7%
	All	**84%**	**93%**	**9%**

Streams or stream segments within portions of the study area zoned for forest use tended to have greater existing and potential shade than did streams or segments in areas zoned for agricultural or rural residential use, although there were a few exceptions to this pattern. Despite their generally lower shade potentials, however, many segments zoned for agricultural or rural residential uses had greater scopes for improvement in shade conditions than did segments in forest areas.

Spatial patterns of variation in existing shade levels, potential shade levels, and scopes for improvement in shade levels within the study area are shown in Figures 20-22. Patterns evident in the figures include:

- Variable but low existing and potential shade levels along the mainstem South Fork.
- More variable but generally higher levels of existing shade along streams in the three tributary watersheds than along the mainstem. Estimated levels of existing shade varied from 22% to 95% among the 86 tributary reaches modeled.
- Consistently high shade potentials along all of the tributary streams. Estimated shade potentials varied from 86% to 95% among the 86 tributary reaches modeled.
- The presence of stream segments with significant scopes for improvement in shade conditions throughout most of the mainstem and at locations within each of the tributary watersheds. The greatest scope for improvement in the study area was an opportunity to increase stream shading by 73% along one of the modeled stream segments in a tributary system.
- The presence of more extensive opportunities for improving shade conditions in the Dement Creek system than in the other two tributary watersheds.
- The presence of multiple east-west trending segments of the lower South Fork that have very low shade potentials related to high natural exposure to mid-summer sun.

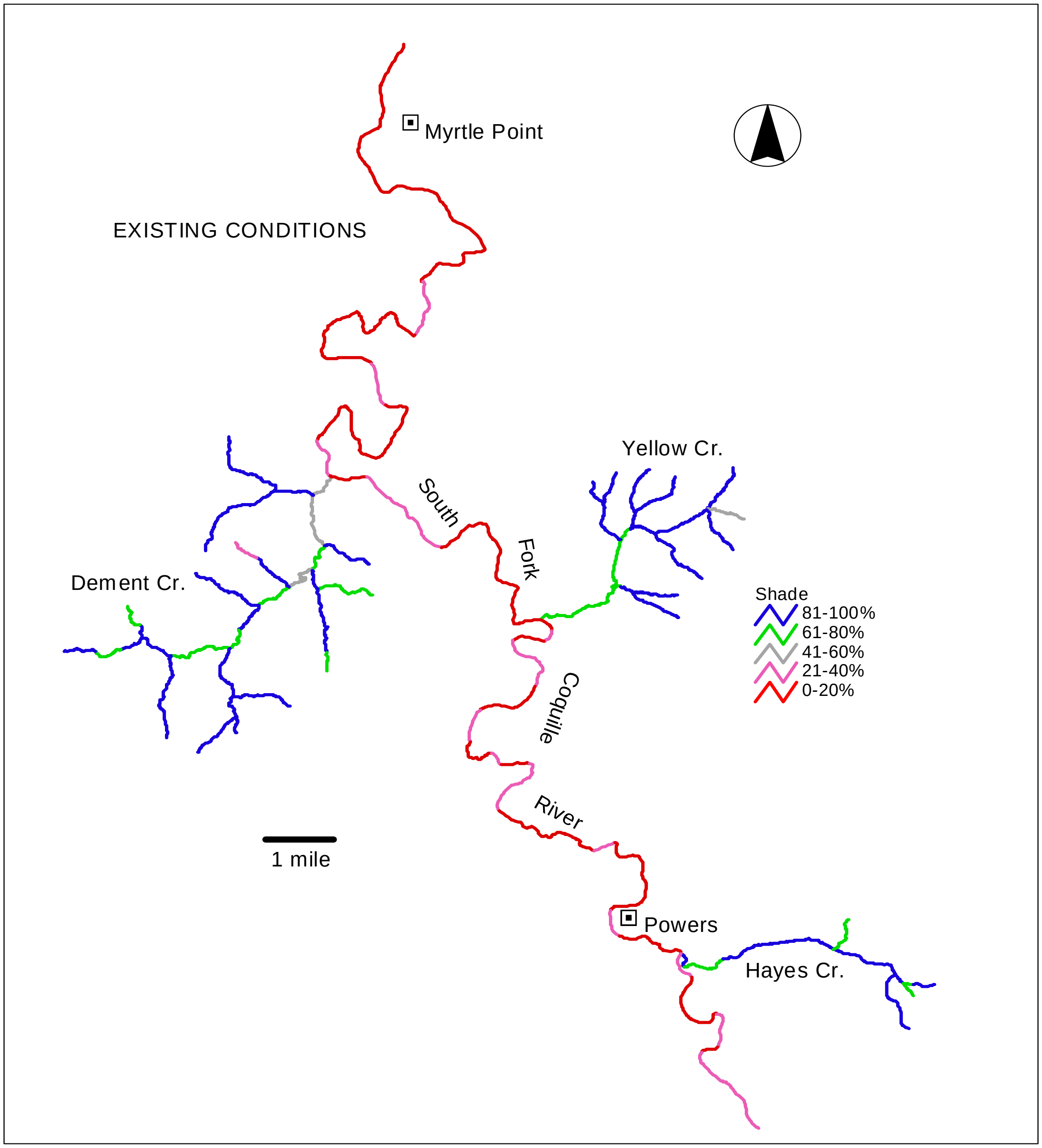

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Figure 20. Spatial variation in existing stream shade within the lower South Fork study area.

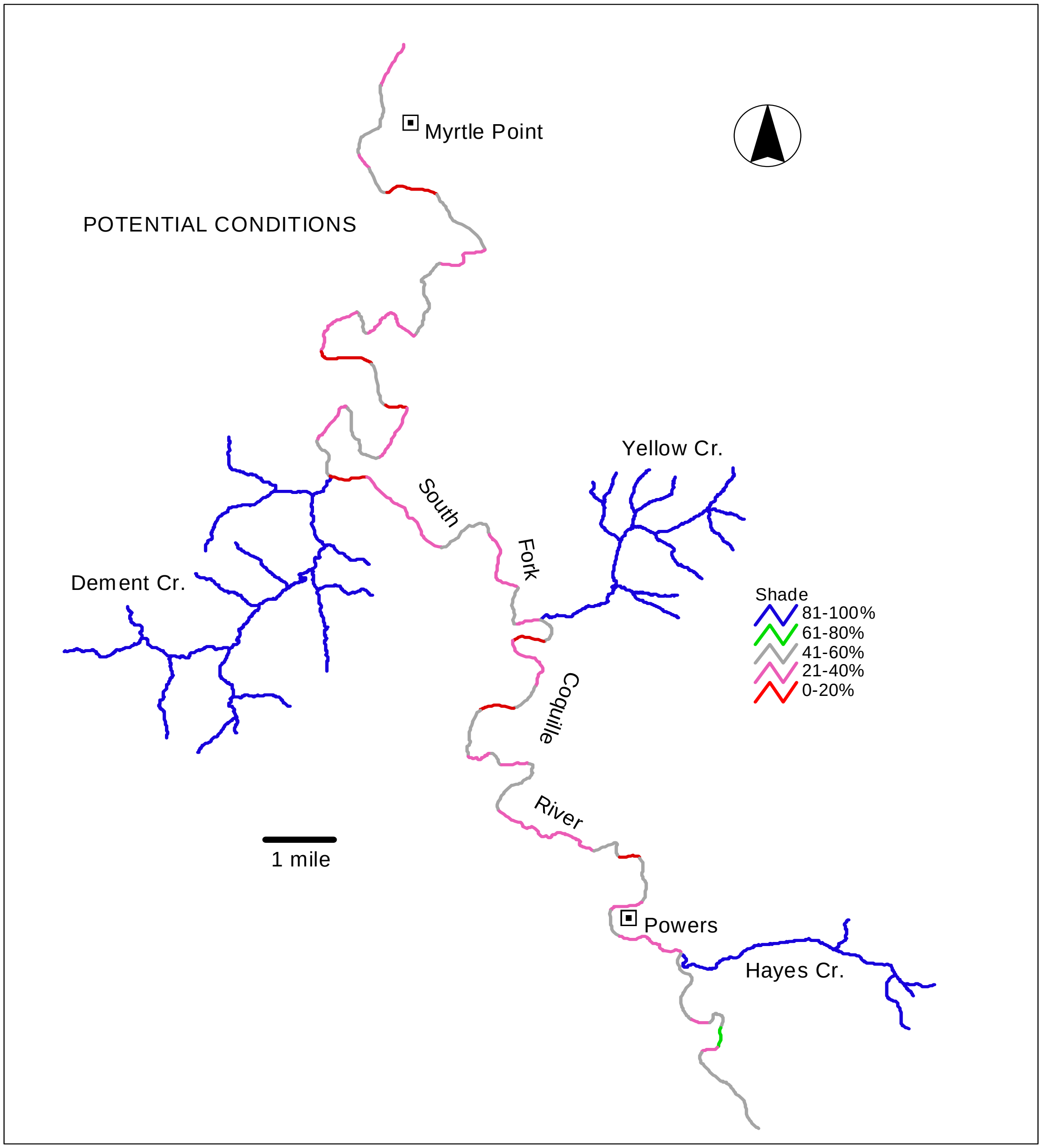

Figure 21. Spatial variation in stream shade potential within the lower South Fork study area.

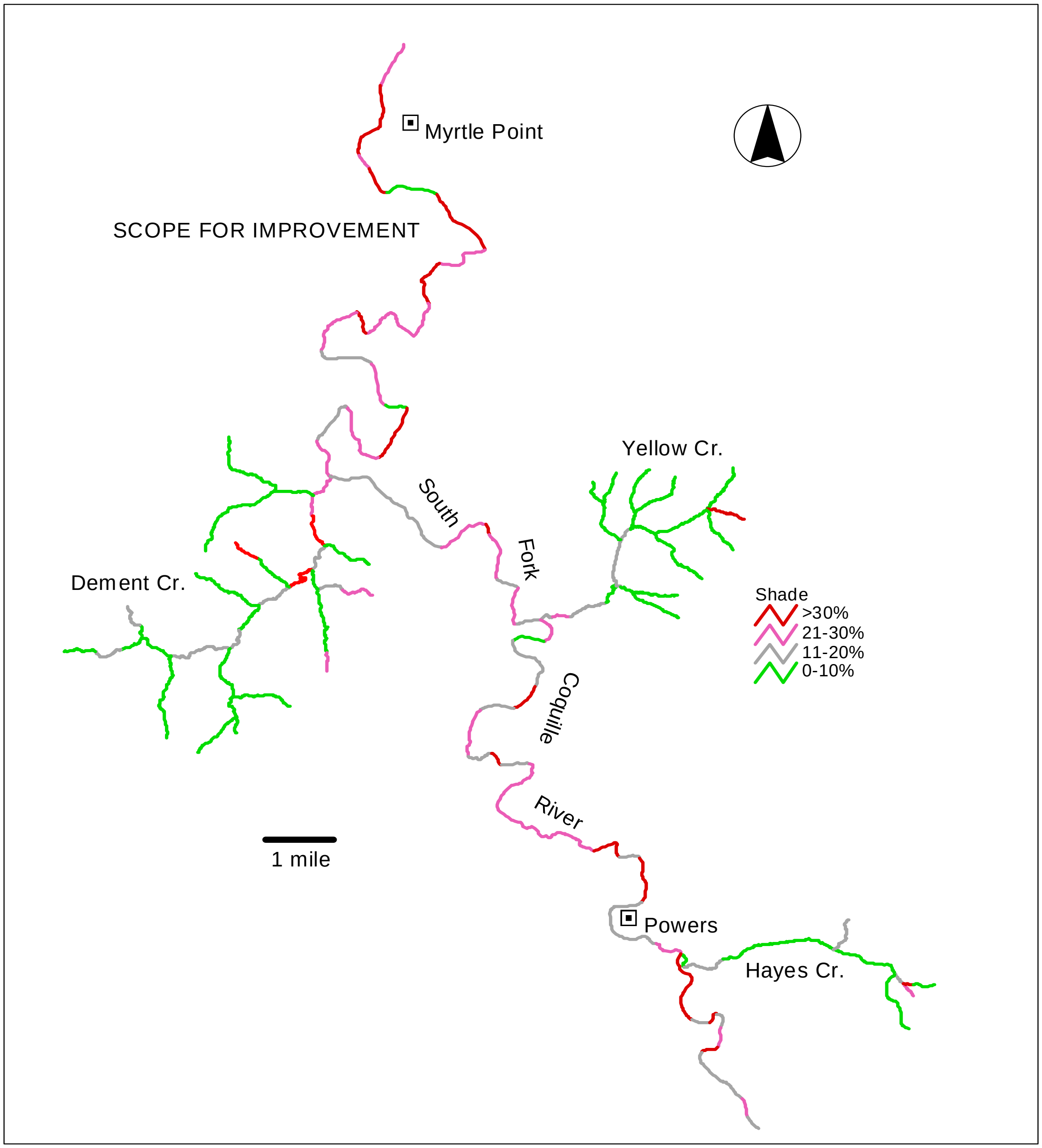

Figure 22. Spatial variation in scopes for improvement in stream shading within the lower South Fork study area.

5. RESTORATION OPPORTUNITIES AND PRIORITIES

There are abundant opportunities for improving riparian conditions along the lower South Fork Coquille River and its tributaries. In the Dement, Yellow, and Hayes Creek watersheds, excluding livestock from near-stream areas and/or planting native riparian vegetation along selected segments of the channel network would improve stream shading, reduce stream temperatures, and increase the quality of available aquatic habitat. Channel segments where riparian improvements would be most helpful in providing additional shade were shown in Figure 22. Similar opportunities for improving habitat exist along the South Fork. However, riparian restoration along the lower-most reaches of the mainstem, particularly below Dement, may be complicated by the highly incised condition of the channel and the combined effect that this incision and currently altered riparian conditions are having on channel stability in many areas.

When considering improvements to riparian conditions along the South Fork, the CWA will want keep several things in mind. These include:

- Altered watershed conditions are affecting the delivery of water, sediment, and wood to the responsive reaches of the lower river.

- Channel simplification (reduced sinuosity) between the Middle Fork and Dement has increased the channel’s slope, the level of incision, and distances between riverbends that absorb energy.

- Riparian vegetation exerts a strong influence on the morphology of channels like those found along the lowest reaches of the South Fork.

- Reduced riparian widths and altered vegetative composition are affecting bank integrity and, in at least some instances, channel form. Historically, the river was bordered by a substantial riparian forest and was unlikely to have gotten an opportunity to erode weakly vegetated floodplains or terraces.

- Gravel mining near Gaylord and below (existing permits could allow a maximum extraction rate of 85,000 cubic yards/year) may be contributing to channel erosion and continued incision. Whether this is actually happening is an important unknown at present.

- Some hard structures placed into or removed from the channel in the past (typically in association with site-specific streambank protection) appear to be contributing to channel changes and bank erosion in some areas.

- Many of the most pronounced areas of bank erosion along the lower river appear to be affected by several of the above factors.

5.1. RIPARIAN RESTORATION ALONG THE LOWER STUDY REACHES

There are multiple basic options for action along the lower-most reaches of the study area, below about Gaylord and particularly below Dement. These are outlined below.

1. *Do nothing*. This option seems likely to be a poor alternative that could well result in continued declines in the stability of the river channel.

2. *Natural River* (make watershed improvements, establish sizeable riparian setbacks, make vegetative plantings, and conduct channel and riparian monitoring). This alternative would require assurances that the period of river down-cutting has ended and would involve giving a portion of the valley floor back to the South Fork as the river slowly re-meandered toward a naturally stable form and developed a new (lower) secondary floodplain. Estimates of the maximum level of set-back that might ultimately be required along the river between Dement and the Middle Fork, potentially several generations of valley residents into the future, were given in Section 3.3.2 of this report. Set-backs for other study reaches would likely be considerably smaller. While moving toward long-term stability, the river would continue to capture substantial volumes of fine sediments as it eroded portions of its banks during large floods. The more successful the riparian restoration proved to be at stabilizing bank toes under this scenario, the more slowly the river would shift position and the smaller the final set-backs.

3. *Strategically Stabilized River* (make watershed improvements, adopt reach-based (collective) riparian restoration approaches that include strategic bank resloping, bioengineering and/or floodplain construction at key locations). This option is a more aggressive version of option 2, above, that emphasizes riparian planting in conjunction with structural solutions at key locations where vegetative approaches alone would be inadequate to prevent toe erosion and periodic geotechnical instability. Identification of these locations would require site-specific analysis incorporating the use of field data, bank stability relationships, and the cumulative experience of success (or failure) that CWA partners have in using willows or other vegetative treatments to stabilize similar sites without bio-engineered toe protection. All restoration planning would need to be done collaboratively at the scale of our study reaches or sub-reaches to avoid unintended (and undesirable) consequences and to assure landowner buy-in. Set-back distances would be smaller and, if carefully implemented, sediment yields to the river from bank erosion could be substantially lower than those associated with option 2. As in option 2, assurance that the period of river down-cutting had ended would be important to giving the effort a meaningful chance of success. Monitoring would be needed, to assure that CWA partners become increasingly effective at working with native materials to the degree possible.

4. *Rock-and-ignore*. The “rock-and-ignore” approach reflects the way in which localized spot-treatments of rock have often applied to eroding riverbanks, without any broader context than to prevent bank loss at a specific site. At whatever scale it is applied, this approach is likely to have high capital costs, damage habitat, and to have unintended consequences. There are multiple instances along the lower South Fork where hardened bank protection measures have failed to yield on-site riparian improvements, exacerbated bank erosion problems in other areas, an/or damaged partially functional riparian areas.

5.1.1. Potential Priority Areas for Early Action Along the Lower South Fork

Several sub-reaches of the lower mainstem appear to be good candidates for early CWA action. These were identified based on the relative abundance of at-risk riverbanks, the presence of a high proportion of weakly vegetated riverbanks in areas of what we judge to be high erosion hazard, or the presence of specific classes of riparian conditions. Listed in descending order of apparent problem severity, these subreaches include 7D, 7H, 7K, 7B, 5B, 1B, 4B, 7I, and 12A.

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