UPDATED GUIDE TO THE REFERENCE VALUES USED IN THE SOUTHERN OREGON/NORTHERN CALIFORNIA COHO SALMON RECOVERY CONSERVATION ACTION PLANNING (CAP) WORKBOOKS

PREPARED BY KIER ASSOCIATES AND
NATIONAL MARINE FISHERIES SERVICE/ARCATA

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FISHERIES AND WATERSHED PROFESSIONALS

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
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COVER: WILD SPAWNING COHO SALMON PHOTO BY WENDELL JONES, CDFG RETIRED

INTRODUCTION

This report is an update and refinement of Kier Associates and National Marine Fisheries Service (NMFS) (2007) in response to recovery planning cooperator comments and new information. NMFS is using the Conservation Action Planning (CAP) workbook model to support species recovery plan development for the Southern Oregon/Northern California coho (SONCC) salmon Evolutionary Significant Unit (ESU). The workbook is a regional adaptation of a tool used worldwide by The Nature Conservancy (TNC, 2005). NMFS has contracted with Kier Associates scientists to gather extensive regional field data concerning aquatic habitat and upland conditions into a custom Microsoft Access database to inform the workbook and to provide a quantitative assessment of coho salmon freshwater habitat quality and the risk of upland contributions of pollution.

By using reliable data from all available sources, and by drawing reference values primarily from the scientific literature, NMFS can provide a tool for cooperation among agencies with parallel missions and responsibilities, across state lines, in the manner proposed by Spence, et al. (1996);

> "If we are to conserve salmonids and their habitats, our management actions can be treated and evaluated just as scientific experiments are, that is, with much more rigorous design and consistent data collection at a multi-state scale."

Processes potentially served by the SONCC CAP include the coho salmon recovery mandated under the federal and State Endangered Species Acts, implementation of the Clean Water Act, and monitoring compliance with the National Forest Management Act.

The data sources used here include those from the California Department of Fish and Game (CDFG), Oregon Department of Fish and Wildlife (ODFW), U.S. Forest Service Region 5 (R5) and Region 6 (R6), California State Water Resources Control Board (SWRCB), Oregon Department of Environmental Quality (ODEQ), California Department of Forestry and Fire Protection (CDF), U.S. Environmental Protection Agency (EPA), the Bureau of Reclamation (BOR), the Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (USFWS), the Yurok Tribe, Karuk Tribe, Hoopa Tribe, U.S. Fish and Wildlife Service (USFWS), Resource Conservation Districts (RCDs), Utah State University's (USU) Bug Lab, the Conservation Biology Institute (CBI) Mattole Restoration Council, Mattole Salmon Group and other contributors.

The project also draws on the extensive aquatic and upland data already captured in the Klamath Resource Information System, or "KRIS", databases, which cover more than a dozen watersheds within the California portion of the SONCC (see www.krisweb.com). KRIS was initially developed to assess fish population and habitat condition trends, including water quality data, to support the Klamath and Trinity River restoration programs. Following its initial funding by the SWRCB, USFWS, and BOR, KRIS projects were completed in other northern California coastal watersheds with funding from CDF, the National Fish and Wildlife Foundation, the Mennen Environmental Foundation, and the Sonoma County Water Agency.

The Kier Associates science team, developers of the KRIS program, has assisted NMFS by adapting the data from the KRIS projects in the SONCC area to support salmon recovery plan development. A master database, developed in Microsoft Access, captures the data acquired from all of the contributors and is used to compute summary values for the Excel SONCC CAP workbook scores.

The purpose of this document, then, is to present the scientific basis for the reference values used in ranking aquatic and upland conditions relevant to coho salmon recovery. Some of the reference values are drawn from the conventions of the agency or entity that provided the data, wherever sufficient scientific basis or metadata has been provided.

HOW THE CAP HAS BEEN ADAPTED

The SONCC CAP database consists of a collection of 45 CAP Excel workbooks, one for each coho population identified by Williams et al. (2006) (Figure 1) and Version 1.0 was published in July 2007. The revision of this document is coincident with production of final SONCC CAP workbooks (V 2.0) that will serve as the basis of final SONCC Recovery Plans.

The creation of the 45 workbooks entailed development of:

1. A customized Microsoft Access database,
2. A set of custom Python computer programs for data preparation, and
3. An adapted Excel CAP workbook.

The Access database stores region-wide data for all indicator- and sources-of-stress data. These data are tagged with spatial coordinates, including stream name, reach codes (LLID), and sub-basin identification so that SONCC CAP summary workbooks for sub-basins or other spatial units can be produced as needed. The Excel SONCC CAP application was worked out between October 2006 and April 2007 using Freshwater Creek, a tributary of Humboldt Bay, as a case study. The pilot workbook project was circulated for review by recovery planning collaborators and improvements to it were then made in response to the reviewers' comments. Version 2.0 of the SONCC CAAP workbooks used Mattole River data for a pilot and NMFS worked closely with the Mattole Restoration Council and Mattole Salmon Group, two local groups that provided new data.

All indicator- and sources-of-stress data were entered directly into the Access database rather than into the individual workbooks. A custom Python software computer program was then developed to transfer the Access data to the 45 copies of the template workbook. This methodology ensures that all 45 workbooks are using the same criteria and setup.

To ensure transparency, all data in the Access database have been tagged with their source of origin and associated with available metadata. The array of results can also be viewed as box plots, so that outliers can be identified and patterns in the data can be easily determined. What follows is a discussion and the bases for the reference values for aquatic integrity ("Indicators" in CAP terminology) and for "Threats" or "Sources of Stress**"**, CAP terminology for upland conditions and their associated risk of impacting coho salmon habitat. Life history stages of coho salmon are chosen as conservation "Targets" within the SONCC CAP.

Data are lacking for some Indicators and Sources of Stress that are recognized as limiting coho salmon production or potentially impairing coho habitat. NMFS staff conducted an extensive review of literature for SONCC coho population watersheds to derive values for those factors. Documents included federal agency watershed analyses, TMDL reports, restoration plans and locally driven watershed assessments. Kier Associates then merged the results generated by NMFS staff into Version 2.0 of the SONCC CAP workbooks.

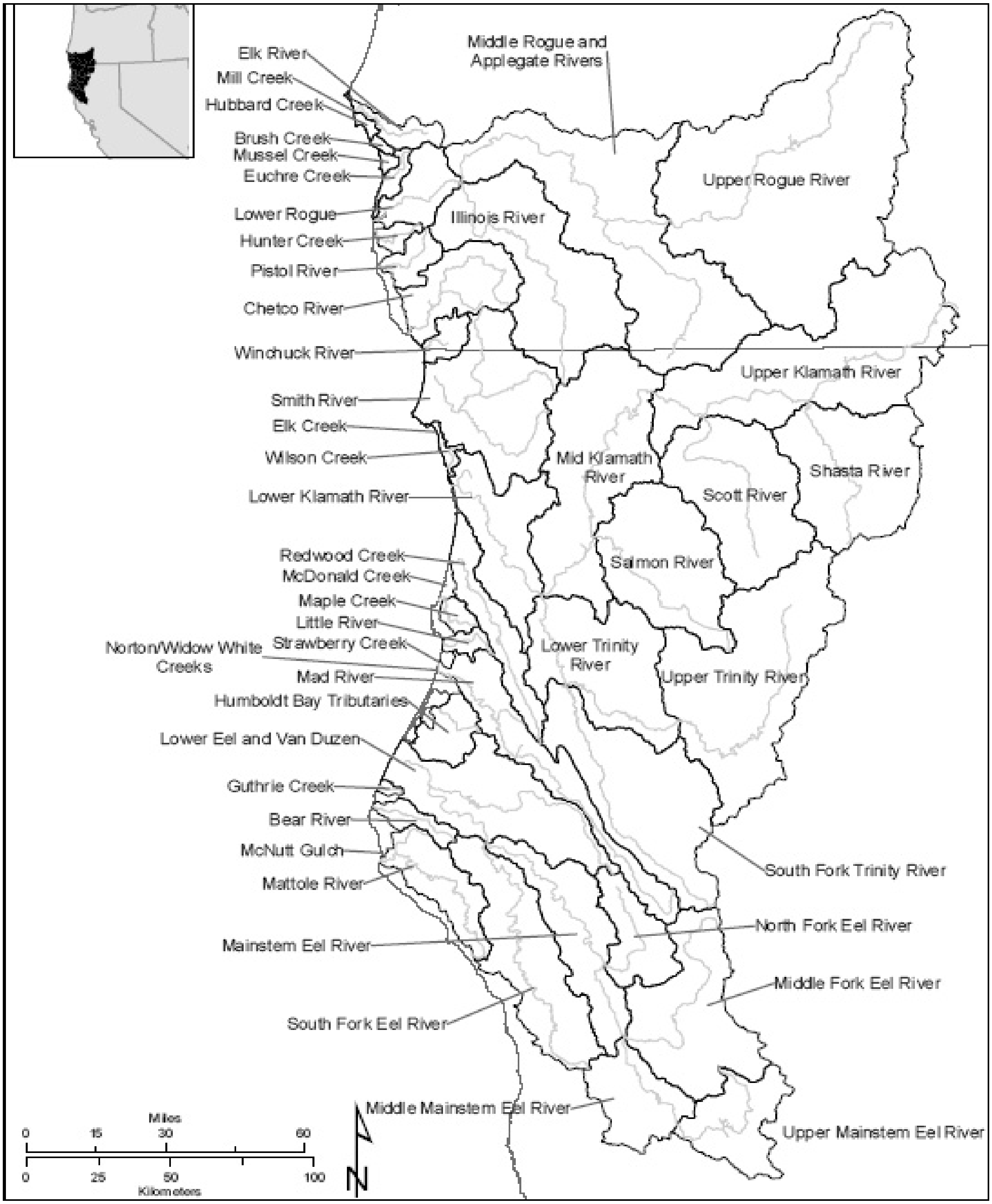

Figure 1. Southern Oregon/Northern California coho salmon populations. Taken from Figure 8, "*Historical population structure of coho salmon in the SONCC Coho Salmon ESU*" of NOAA/NMFS's Technical Memorandum 390 (Williams, et al. 2006).

REFERENCES FOR CAP AQUATIC INDICATORS

The reference values below for aquatic health (Indicators) reflect the habitat needs of coho salmon based on the best available scientific literature. Many of the documents cited below for support were assimilated by Kier Associates as part of this project and made available to NMFS in electronic form. Targets represent values characteristic of control streams, with the long-term objective of bringing impaired streams back to a "natural range of variability" that supports all life history phases of coho salmon (Spence et al., 1996; Rieman et al., 1993). Table 1 provides a summary of most of the Indicators used in the SONCC CAP database and discussion of the scientific bases for the recommended reference values follows.

Table 1. Indicators of aquatic habitat suitability for coho salmon and CAP reference values.

Indicators	**Poor**	**Fair**	**Good**	**Very Good**
Aq Macroinverts (EPT)	<=12	12.1-17.9	18-23	>23
Aq Macroinverts (Richness)	<25	25-30	30-40	>40
Aq Macroinverts (B-IBI)	<40	40-60	60.1-80	>80
Embeddedness	>45%	35.1-45%	25.1-35%	<=25 %
Pool Depths	<2 Ft	2-3 ft	3-3.3 ft	> 3.3 ft.
Pool Frequency (length)	<35%	35-40%	40-50%	>50
Pool Frequency (area)	<10%	10-20%	20-35%	>35%
Barrier (habitat dry)	>5%	1-5%	<1%	0%
LWD (key pieces/mi.)	>1	1-2	2-3	>3
LWD <20 ft. wide	>35 pieces/mi	35-53 pieces/mi	54-84 pieces/mi	<85 pieces/mi
LWD 20-30 ft. wide	>25 pieces/mi	26-36 pieces/mi	37-64 pieces/mi	<65 pieces/mi
LWD >30 ft. wide	>16 pieces/mi	16-33 pieces/mi	33-60 pieces/mi	<60 pieces/mi
Canopy Cover	<60% shade	60-70% shade	70.1-80% shade	>80% shade
Canopy Type	>40% Open+HW	30-40% Open+HW	20-30% Open+HW	<20% Open+HW
Riparian Condition (conifers >36" dbh / 1000ft for 100 ft wide buffer)	<75	75.0-125	125-200	>200
D50 (median particle size)	<38 mm >128 mm	38-50 & 110-128	50-60 & 95-110	60-95 mm
% Sand <6.4mm (wet)	>30%	25-30%	15-25%	<15%
% Sand <6.4mm (dry)	>25.8%	21.5-25.8%	12.9-21.5%	<12.9%
% Fines <1mm (wet)	>17%	15-17%	12-15%	<12%
% Fines <1mm (dry)	>12.6%	11.1-12.6%	8.9-11.1%	<8.9%
VStar	>0.25	0.21-0.25	0.15 - 0.21	<0.15
Temperature (MWAT)	>17ºC	16.1-17ºC	15-16ºC	<15ºC
Turbidity	>720 hrs >25 fnu	361-720 >25 fnu	120-360 hrs >25 fnu	<120 hrs >25 fnu
pH (annual maximum)	>8.75	8.5-8.75	8.25-8.5	<8.25
D.O. (COLD) (mg/l 7-DAMin)	<6.0 mg/l	6-6.5 mg/l	6.5-7.0 mg/l	>7.0 mg/L
D.O. (SPAWN) (mg/l 7-DAMin)	<9 mg/l	9-10 mg/l	10-11 mg/l	>11.0 mg/l

Aquatic Insects: Barbour et al. (1999) point out the value of using aquatic benthic macroinvertebrates (BMIs) for evaluating water quality and they are also recognized as a very important food source for coho salmon fry, juveniles and smolts (Spence et al., 1996). BMIs have been used extensively in California for understanding watershed health for more than a decade (Harrington, 1999) and there is increasing interest in their use by agencies such as the State Water Resources Control Board (SWRCB), Department of Fish and Game, the U.S. Environmental Protection Agency (EPA), the U.S. Forest Service (USFS) and the Bureau of Land Management (BLM).

A Benthic Index of Biotic Integrity (B-IBI) can be developed that uses BMIs to allow a regional ranking of stream health. Ode et al. (2005) established a B-IBI for southern California streams based on widespread samples that included a number of lightly or undisturbed (reference) watersheds. The current SONCC CAP exercise utilizes a provisional B-IBI derived for northern California (Rehn and Ode, 2005).

The Rehn and Ode (2005) north coastal California provisional B-IBI is based on 257 samples collected between 2000-2003. Samples met California State Bioassessment Protocols (Harrington, 1999) or newer California Aquatic Macroinvertebrate Laboratory network (CAMLnet) level 1 standard taxonomic effort (CDFG, 2002). Only riffle samples were used and the standard number of organisms counted was a sub-sample of 500.

The Rehn and Ode (2005) provisional B-IBI for northern California streams covers three ecoregions (Omernik, 1987): Chaparral, Coastal and Klamath Mountains. They found that six of eight metrics that comprise the IBI for reference sites were significantly lower in the Chaparral ecoregion and than in Coastal and Klamath ecoregions, which were similar. The SONCC does not include any of the Chaparral ecoregion; therefore, reference values for that ecoregion do not apply in this project.

Reference ratings in SONCC CAP for the B-IBI samples are the same as Rehn and Ode (2005): Very Good = >80, Good = 60-80, Fair = 40-60, Poor = <40. One exception is that they use Poor (20-40) and Very Poor (<20) categories that have been combined in the SONCC CAP because streams with B-IBI scores below 40 are assumed to be unsuited to coho survival.

In addition to northern California B-IBI data from Rehn and Ode (2005), data from the Pacific Lumber (PL) Company Habitat Conservation Plan (HCP) (PL, 1998), the Humboldt County Resource Conservation District (Friedrichsen, 1998) and the BLM and Utah State University (USU) National Aquatic Monitoring Center were acquired (www1.usu.edu/buglab/). The PL and Humboldt RCD samples followed California Bioassessment Protocols (Harrington, 1999). USU kicknet riffle samples use standard techniques (Vinson and Hawkins, 1996), but more than 500 organisms are typically identified. Consequently, USU samples were sub-sampled by Kier Associates to 500 specimens after adjustments were made to standardize taxa to conform to the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) standard taxonomic effort (Rogers and Richards, 2006).

Two other standard aquatic macroinvertebrate sampling measures are used in the SONCC CAP, the EPT and the Richness metrics. EPT stands for three orders of pollution intolerant insects: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). The metric used is one based on the number of EPT taxa present and SONCC CAP reference values are similar to Rehn and Ode (2005) (Table 4): Very Good = >23, Good = 18-23, Fair = 12.1-17.9 and Poor = <=12.

The Richness metric is the total number of macroinvertebrate taxa present and SONNC CAP ranges are loosely based on the Russian River B-IBI (Harrington et al., 1999), which is in the Chaparral ecoregion. A total of 36 taxa received the highest aquatic health score, but that value has been adjusted upward to reflect Coastal and Klamath Mountain ecoregional diversity: Very Good = >40 taxa, Good = 30-40, Fair = 25-30 and Poor = <25. Richness is only used for PL samples where EPT values were not supplied.

Embeddedness: The degree to which cobbles or gravel at pool tail crests are buried in fine sediment or sand is known as embeddedness, a measurement made routinely in salmonid habitat typing surveys (CDGF, 2004). Pool tail crests are often chosen as locations for coho salmon redd construction. Embeddedness, therefore, is a measure of spawning habitat quality. Female coho may expend considerably more energy excavating redds, for example, if embeddedness is high. High levels of embeddedness are indicative of high fine sediment supplies, which can resettle after redd construction to decrease egg and alevin survival. Coho salmon fry and juveniles can hide within the interstitial spaces of a cobbled stream. Embeddedness is therefore also an inverse index of available cover for coho salmon fry and juveniles.

Armentrout et al. (1999) set targets for embeddedness in volcanic watersheds west of Mt Lassen, in Mill, Deer and Antelope creeks as follows: less than 10% for mainstems, less than 15% for tributaries without highly erodible soils (rhyolite), and less than 20% for tributaries in watersheds with rhyolitic soils.

CDFG (2004) rated embeddedness scores of less than 25% as good, while NMFS (1996) rated embeddedness of less than 20% as properly functioning. NMFS (1996) also gave an "at risk" rating of 20-30% and a "not properly functioning" value to embeddedness greater than 30%. CDFG habitat typing data cannot be used to discern embeddedness less than 25%; therefore the SONCC CAP rating reference values are Very Good = <25%, Good 25-30%, Fair 30.1-45% and >45% as Poor.

Pool Depth: CDFG (2004) habitat typing surveys always capture data on pool depth, which is the best replicable metric for trend monitoring that comes from such surveys. Stream habitat surveys in Oregon conducted by the U.S. Forest Service and the Oregon Department of Fish and Wildlife also measured pool depth. Greater pool depth provides more cover and rearing space for coho and other juvenile salmonids. Deeper pools also create better shelter for migrating and spawning adults. Pool depths of three feet, or one meter, are commonly used as a reference for fully functional salmonid habitat (Overton et al., 1993; USFS, 1998; Bauer and Ralph, 1999; Brown et al., 1994), although much deeper pools are expected in higher order streams.

The North Coast Regional Water Quality Control Board (2006) cited CDFG's ranking of pool depth:

> "According to the *California Salmonid Stream Habitat Restoration Manual, Third Edition* (2004), PRIMARY POOLS are defined as follows: For 1st and 2nd order streams, primary pools are defined as having a maximum residual depth of at least two feet, occupy at least half the width of the low flow channel, and be as long as the low flow channel width. For 3rd and 4th order streams, a primary pool must have a maximum residual depth of at least three feet, occupy at least half the width of the low flow channel, and be as long as the low flow channel."

Because there are insufficient data to understand stratification by stream size, pools greater than a meter are characterized as Very Good regardless of stream order, and pools less than two feet deep in any stream are Poor. Maximum pool depth is partly a function of watershed size, but pool depths and volume can be compromised by sediment over-supply or increased peak discharges related to upstream or upslope land management (Montgomery and Buffington, 1993).

Pool Frequency: Habitat typing surveys (CDFG, 2004) also provide data on the percentage of stream reaches represented by pools, which are preferred habitat for juvenile coho (Reeves et al, 1988). Pool frequency by percent length is preferable to pool frequency by occurrence because the latter may give a false impression of health if there are numerous, shallow, short pools as a result of aggradation. Reeves et al. (1993) found that pools diminished in frequency in intensively managed watersheds. Streams in Oregon coastal basins with low timber harvest rates (<25%) had 10-47% more pools per 100 m than did streams in high harvest basins (>25%). Alaska studies showed ranges of 39-67% percent pools by length (Murphy et al., 1984). The Washington State Fish and Wildlife Commission (1997) recommend the following pool frequencies by length:

> "For streams less than 15 meters wide, the percent pools should be greater than 55%, greater than 40% and greater than 30% for streams with gradients less than 2%, 2-5% and more than 5%, respectively."

California habitat typing surveys are rarely conducted in channels of greater than 2% gradient; therefore, no screen for gradient is needed for California SONCC data. Peterson et al. (1992) used 50% pools as a reference for good salmonid habitat and recognized streams with less than 38% pools by length as impaired. Values from Peterson et al. (1992) are those adopted for use in the SONCC CAP: Poor = <35%, Fair = 35-40%, Good = 40-50%, Very Good =>50.

The Oregon Department of Fish and Wildlife (ODFW, 2001; 2002a) uses pool area as a measure of frequency and their ratings for habitat quality range from less than 10% equaling Poor, to greater than 35% pools as Good (ODFW, 2002b). SONCC CAP ratings reflect ODFW bench marks.

Dry Stream Segments: Habitat typing surveys note reaches of stream that lack surface flow as "dry" (CDFG, 2004). Dry stream reaches are sometimes the result of stream diversions, but can also be caused by aggradation of the streambed resulting in loss of surface flows seasonally (Kier Associates, 1999; Nielsen et al., 1994). The lack of connectivity of rearing habitats can prevent the movement of juvenile coho salmon and other salmonid species, and thus is used in the CAP as a fish passage indicator. CAP references are: > 5% dry = Poor, 1-5% = Fair, <1% = Good and no dry reaches = Very Good.

Large Wood in Streams: The ODFW Aquatic Inventory Project collected data for many stream reaches, mostly on private land, within the SONCC, including that concerning the presence of large wood in the streams. Coho salmon juveniles favor pools formed by large wood (Reeves et al., 1988) and an abundance of large wood increases pool formation (Sedell et al., 1988). Therefore, wood frequency is a good indicator of juvenile coho salmon habitat quality. The ODFW "key pieces" (Schuett-Hames et al. 1999) data was chosen as the SONCC CAP metric, while the volume of large wood per 100 meters of stream length and the number of pieces are not used. If there are three key pieces per 100 m ODFW (2002b) rates a stream as good, whereas less than one key piece is indicative of poor conditions. ODFW (2002a) references are based on the 65th percentile of samples of streams flowing in late seral forests for Good rankings and the lower 25th percentile of habitat surveys for Poor ratings.

Large wood data for the Oregon portion of the SONCC is also available from the Siskiyou National Forest, which surveyed aquatic habitat at over 400 sites as part of a Rogue River CAP project being conducted in cooperation with the Nature Conservancy (SNF and TNC, 2006). Their large wood ratings are based on variable stream widths and a frequency distribution of samples and expressed as the number of wood pieces per mile. The SONCC CAP adopted those criteria, scoring each reach on a 1-4 scale according to stream width and the number of wood pieces per mile on federal lands. Final wood scores for the CAP workbooks were obtained by taking the median score of all reaches within a given population.

Canopy: CDFG (2004) habitat typing surveys measure canopy closure from the middle of streams, which is a good index of shade, but does not supply information about overall riparian condition. Shade is an important influence on water temperature and CDFG (2004) recognizes 80% canopy as optimal for salmon streams. The CAP ratings are >80% = Very Good, 70-80% = Good, 60-70% = Fair and < 60% = Poor.

Canopy Type: CDFG (2004) habitat surveys do provide information on the type of canopy: coniferous, deciduous and open. The SONCC covers primarily coastal watersheds dominated by coniferous forests and the CAP ratings reflect hardwood-dominated conditions as likely resulting from disturbance. Consequently, greater than 80% conifer likely reflects pre-disturbance or fully recovered conditions and is ranked as Very Good. If the combination of hardwoods and open canopy exceed 40%, the CAP rating is Poor because of potential warming from the inadequate thermal buffering associated with early seral conditions(Essig, 1998), where hardwoods have replaced conifers. The Canopy Type metric will only be applied in SONCC basins where conifers are dominant, not in interior basins or on different geologic types that naturally produce hardwoods or grasslands.

Riparian Conditions: ODFW (2002a) measures riparian health by surveying large conifers in a band that extends 100 feet back from the edge of the active channel and extends for 1,000 feet downstream. The SONCC CAP has adopted the measure employing trees with diameter at breast height (dbh) of greater than 36 inches. The ODFW (2002b) habitat benchmark for this factor is fewer than 75 per 1,000 feet is Poor, while more than 200 is Good. The reference values used in the CAP are: <75 = Poor, 75.0-125 = Fair, 125-200 = Good, and >200 = Very Good.

The USFS (2000) *Reconnaissance Level Assessment for the National Forest of the Pacific Southwest Region* provides stream corridor vegetation ratings based on professional judgment per the descriptions in Table 2, which represents a combination of field observation and professional judgment. The USFS rating system defines Fully Functional as less than 10% disturbance (5% recent) and is equivalent to the SONCC CAP Very Good. Partially Functional is 10-25% disturbed (5-10% recent) and it will be scored as a Fair in the CAP. Non-Functional will equal Poor in the CAP, which is greater than 25% disturbance (>10% recent).

Median Particle Size (D50): Knopp (1993) studied 60 northwestern California streams and determined a relationship between streambed median particle size, "D50" and watershed disturbance. Reduced median particle size is often associated with increased sediment loads and increased bedload mobility (Montgomery and Buffington, 1993), which can cause egg and alevin mortality (Nawa et al., 1990). Increased peak flows resulting from watershed disturbance, particularly in the transient snow zone (Berris and Harr, 1987), cause additional shear stress on the streambed and can result in an increase in D50 (Montgomery and Buffington, 1993). All D50 survey data available for the SONCC, including those collected by Knopp (1993), are from low

Table 2. U.S. Forest Service Region 5 Watershed Analysis aquatic Indicator descriptions (USFS, 2000).

Indicator	Fully Functional	Partially Functional	Impaired
Stream Corridor Vegetation	No more than 10% of riparian in less than proper functioning condition. No disturbance to less than 5% of streamside zone...	Between 10-25% of the stream corridor area vegetation not meeting properly functioning condition. From 5-10% recent disturbance.	More than 25% of the riparian zone not in proper functioning condition. More than 10% has experienced recent disturbance.
Floodplain Connectivity	Greater than (80%) response reaches and parts of response reaches within the watershed demonstrate floodplain connectivity	Only some (50-80%) response reaches have inundation of historic floodplains by bankfull flows.	Few (<50%) response channels in the watershed display floodplain connectivity.
Water Quantity/Flow Regime	Hydrograph has no alteration from natural conditions. Flows support availability of aquatic habitat	The timing, rate of change and/or duration of mid-range discharges may impair aquatic habitat availability but peaks and low flows remain unaltered.	Peak flows and low flows significantly depart from a natural hydrograph. Impairing aquatic habitat availability and/or are resulting in changes to channel morphology

gradient response reaches as opposed to supply and transport reaches of steep and confined headwater channels.

Knopp (1993) recognized a D50 of 38 mm or less as correlating with intensive watershed management. The U.S. Forest Service Pacific Northwest Forest and Range Experiment station has developed the Ecosystem Management Decision Support (EMDS) model (Reynolds, 2001; Reeves et al., 2003) that rates habitat parameters in terms of their suitability for salmonids. Fully favorable median particle size distribution for salmonids according to EMDS falls within the range of 60-96 mm; partially favorable conditions extend from 45 mm to 60 mm and from 96 mm to 128 mm (Ward and Moberg, 2004). The CAP rating combines the EMDS rating curve and Knopp (1993): Very Good = 60-95 mm, Good = 50-60 & 95-110, Fair = 38-50 & 110-128, and Poor = <38 mm >128 mm.

<u>Fines Sediment (< 1mm)</u>: Sediment less than 1 mm in diameter can reduce bed permeability and reduce coho salmon egg and alevin survival thereby (McNeil and Ahnell, 1964). McHenry et al. (1994) measured conditions inside redds and the resulting salmonid alevin emergence in Olympic Peninsula streams and found that when wet-sieved fine sediment samples of 0.85 mm or less were greater than 13%, the survival of coho salmon and steelhead eggs approached zero. In Freshwater Creek, Barnard (1992) found that fine sediment (<1 mm) outside the redds was on average 13% and 7% inside the redds. This suggested that Freshwater Creek met optimal conditions for salmonid spawning in 1988 after about a 40-50 year period of recovery after logging.

Regional sediment reduction plans by the U.S. EPA (1998, 1999) and the North Coast Regional Water Quality Control Board (2006) use the threshold of 0.85 mm for fine sediment and a target of less than 14%. The NMFS (1996) *Draft Guidelines for Salmon Conservation* recognized less than 12% fines less (<0.85 mm) as Properly Functioning Condition, 12-17% as At Risk and greater than 17% as Not Properly Functioning. CAP values for fines less than 1 mm are consistent with these references: Very Good = <12%, Good = 12-15%, Fair = 15-17%, and Poor = >17%.

Fines less than 1 mm have an affinity for moisture and dry sieve samples may be substantially lower than wet sieve samples as a result. According to Shirazi and Seim (1979), a conversion factor of 0.739 can be applied to dry-sieved samples less than 0.85 mm to make them comparable to wet sieved samples. This produces SONCC CAP reference values for dry sieve samples of >12.9% = Poor, 11.1-12.6% = Fair, 8.9-11.1% = Good and <8.9% = Very Good.

<u>Sand-sized Particles (<6.4mm)</u>: Fine sediment less than 6.4 mm is sand and very small gravel that can infiltrate into the cobble-gravel matrix above redds, reduce permeability, cause coho salmon egg mortality, and prevent the emergence of alevin (McNeil and Ahnell, 1964). Kondolf (2003) surveyed the literature and found that when wet-sieved samples of fines less than 6.4 mm exceeded 30% that greater than 50% salmonid egg mortality resulted. The *Garcia River TMDL* (U.S. EPA, 1998) set a target of <30% for fine sediment <6.4 mm and the NCRWQCB (2006) recognizes this same standard. The CAP reference adopts the upper limit for suitability of coho of 30% fines less than 6.4 mm: Very Good = <15%, Good = 15-25%, Fair = 25-30%, Poor = >30%.

Again, dry sieve samples, while a standard stream substrate sampling technique, yield different results than wet sieve samples. Shirazi and Seim (1979) recommended a correction factor of 0.866, when comparing wet and dry sieved sediment samples <6.4 mm. The resulting adjusted SONCC CAP reference values are: Poor = >25.8%, Fair = 21.5-25.8%, Good = 12.9-21.5%, and Very Good = <12.9%.

<u>Silt/Sand Surface (% riffle area)</u>: ODFW (2002a) habitat surveys measure surface fine sediment at pool tail crests, similar to the USFS *Aquatic Riparian Ecosystem Monitoring Protocols* (Gallo et al., 2001). This is different than the fines and sand criteria discussed above, which concerns sediment particles from within the streambed substrate. ODFW (2002b) rates habitats in southwest Oregon as Poor if surface fines are over 15% and Good if they are under 5%. The SONCC CAP reference for surface fines is consistent with ODFW (2002b), but follows the recommendations of Gallo et al. (2001) more closely: Poor = >17%, Fair =15-17%, Good = 12-15%, and Very Good = <12%.

<u>Sediment in Pools (V*)</u>: Pool volume is a good surrogate for juvenile coho rearing space and stream carrying capacity because of the species' recognized preference for pools (Reeves et al., 1988). Hilton and Lisle (1993) devised a method to quickly assess the ratio of the volume of sediment and water in a pool to the volume of sediment alone, to determine the residual volume of pools, and termed the measure V-star or V*. Knopp (1993) found a high correlation in northwestern California between the intensity of land use and residual pool volume as reflected by V*, with highly disturbed watersheds having values greater than 0.21. Regional TMDLs (U.S. EPA, 1998) and the NCRWQCB (2006) both use a V* score of 0.21 as a target for fully functional conditions. NMFS SONCC CAP V* reference values reflect the findings of Knopp (1993) and the TMDL and NCRWQCB recommendations: Poor = >0.25, Fair = 0.21-0.25, Good = 0.15 - 0.21, Very Good = <0.15.

<u>Turbidity</u>: Turbidity is a measure of the ability of light to pass through water and the data are reported in nephelometric turbidity units (NTU) or formazin nephelometric units (FNU). These measurements are equivalent with each derived using slightly different types of equipment and different portions of the light spectrum, and they are used interchangeably in these discussions. Turbidity affects the ability of juvenile salmonids to find food; consequently it can reduce growth rates and survival (Sigler et al., 1984). Higher levels of turbidity can be directly injurious to coho at all life stages (Newcombe and McDonald, 1991). Klein et al. (2005) used a model to demonstrate impacts from elevated turbidity on steelhead juvenile growth, ocean survival and recruitment into the adult population and similar relationships would apply to coho salmon.

The Oregon Department of Environmental Quality's (ODEQ, 2005) exhaustive review of literature on turbidity concurs with Newcombe (2003) that while the duration of exposure is important, 25 ntu should be a benchmark for impairment of salmonids:

> "This is not out of line with Newcombe's (2003) assessment model regarding clear water fishes which predicts that a long-term turbidity level of 25 NTUs would be at the threshold for 'severely impaired' or 'poor' water quality conditions."

Klein (2003) and Klein et al. (2005) demonstrated a strong relationship between watershed disturbance rates and the level and duration of turbidity in northwestern California streams. They analyzed data from undisturbed reference watersheds as well as those with varied intensity of management. Streams flowing from reference watersheds had a 10% exceedance average of 13 FNU, while streams flowing from moderately impacted watersheds had a 10% of 20 FNU, a high impact watersheds averaged 61 FNU. The SONCC CAP reference levels for turbidity are based in part on the analysis of Klein (2003) and Klein et al. (2005): Poor - >720 hrs. >25 fnu, Fair = 361-720 hrs. > 25 fnu, Good = 120-360 hrs >25 fnu, Very Good = <120 hrs >25 fnu.

<u>pH</u>: The pH of water is the standard measure of its acid or alkaline condition. Both acid (<6.5) or alkaline conditions (>8.5) can cause stress to salmonids (Spence et al., 1996). Levels of pH over 9.5 are directly lethal to salmonids (Wilkie and Wood, 1995). Prolonged exposure to pH levels of 8.5 or greater may exhaust the ion exchange capacity at gill membranes and lead to increased alkalinity in the bloodstream of salmonids (Wilkie and Wood 1995).

CAP SONCC references for pH are drawn from the NCRWQCB (2004) *Basin Plan* and the *Water Quality Control Plan for the Hoopa Valley Indian Reservation* (Hoopa TEPA, 2006). Acid conditions are not known to occur anywhere in the SONCC; therefore, no lower limit for pH is offered in the SONCC CAP. Alkaline conditions are, however, recognized as limiting water quality and salmonid production in the Klamath River (Hoopa TEPA, 2006).

The reference values for pH reflect maximum annual values. The array of data suggests that relatively high pH values can sometimes occur at certain locations, like the lower Trinity River, that are not chronically water quality impaired or nutrient rich. Final SONCC CAP references are fit to the frequency distribution of the data. Future queries analyzing pH data and salmonid suitability should consider other metrics that more accurately reflect ambient conditions and not simply infrequent or transitory conditions. Such metrics could include a frequency of exceedance of a threshold value, or a moving 7-day average of daily maximum values (Hoopa TEPA, 2006).

<u>Dissolved Oxygen (D.O.)</u>: Salmonids evolved in cold, oxygen-rich streams. The effects of low D.O. varies according to life history phase. Juvenile salmonid swimming capability diminishes at less than 7 mg/l of D.O. (Reiser and Bjornn, 1979). The NCRWQCB (2005) proposed a standard of 8.0 mg/L seven day floating average minimum (7DAMin) to meet coldwater fish rearing beneficial uses of water ("COLD"). The egg is the most sensitive of all life stages and the NCRWQCB (2005) recommends 8 mg/l for egg development. A loss of 3 mg/l, however, between surface water and water in the redd is assumed. Therefore, the surface water standard during spawning periods ("SPAWN") is 11 mg/l. CAP references reflect these same needs of coho salmon, although D.O. requirements are applied only during the appropriate season. Reliable D.O. readings are primarily from the mainstem Klamath River (Hoopa TEPA, 2006) during summer rearing and migration periods. Little D.O. data, if any, is collected in seasons of adult migration or egg incubation.

As in the case of pH, the selection of minimum values for D.O. data gave a wrong impression of ill health at some locations known to be unimpaired. References were changed to reflect the frequency distribution of the data, resulting in a value of greater than 7 mg/l as meaning Very Good with a range to <6 mg/l rated as Poor.

Temperature: Spence et al. (1996) ranked water temperature as the most important salmonid habitat variable:

> "Stream temperatures influence virtually all aspects of salmonid biology and ecology, affecting development, physiology, and behavior of fish, as well as mediating competitive, predator-prey and disease-host relationships."

There are a number of literature summaries concerning the water temperature requirements of Pacific salmon (McCullough, 1999; Sullivan et al., 2000; U.S. EPA, 2003). The U.S. EPA (2003) *Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* sets standards by life stage for Pacific salmon species. U.S. EPA Region 10 recommendations have been adopted by Oregon (2005) and are proposed by the NCRWQCB (2005) for the California portions or the SONCC.

Ideally water temperature guidelines in the SONCC CAP would reflect the five life history stages of coho salmon, but current available water temperature data are nearly all collected during summer rearing periods. In the near term the CAP will gauge suitability for only the fry, juvenile and smolt stages through the use of the maximum floating weekly average temperature (MWAT). This summary statistic is regarded by the NCRWQCB (2005) as a good index of cumulative salmonid stress and it is used in other regional studies (Lewis et al., 2002).

Work by Welsh et al (2001) and Hines and Ambrose (1998) in northwestern California found that coho salmon juveniles were absent in streams where the MWAT exceeded 16.8 C. In the first version of the CAP, references for suitability for summer rearing will be: Very Good = <15 C, Good = 15-16 C, Fair = 16.1-17 C, Poor = >17C.

As data from a wider range of seasons become available, it would be desirable to assess temperature by life history phase. A discussion of potential references follows.

McCullough (1999) notes that severe winter cold water temperatures may be more limiting than warm summer temperatures and should not be overlooked in analysis:

> "Importantly, the sensitivity in survival rate to a 1°C decrease in wintertime temperature is much greater than to a 1°C increase in summertime temperature when temperatures are at the edges of the optimum winter or summer temperature range. That is, survival can decrease from 100% to 0% with as little as a 2-3°C temperature decrease for incubating eggs during the winter…..A prolonged decrease of as little as 1°C during winter can result in weeks of additional incubation."

Fully developed water temperature guidelines by life stage, adapted from EPA (2003) recommendations, are presented in Table 3. These will be applied in the future as more data for late fall and winter are collected and additional resources become available for analysis. The U.S. EPA (2003) target for salmon core rearing areas in the middle and upper reaches of streams is 16C/61F, which is consistent with the MWAT reference described above. Migratory routes or non-core rearing areas in middle and lower reaches of salmon streams should maintain temperatures of 18C/64F or less. U.S. EPA (2003) recommends an absolute maximum water temperature of 20C/68F during adult or juvenile salmon migration. Spawning salmon were recognized as needing temperatures no more than 13C/55F and temperatures of less than 14C/57F are required for optimal smolting.

Table 3. Water temperature references by life stage used in the SONCC CAP.

Life Stage	Very Good	Good	Fair	Poor
Egg	6-10 C	5-6 C & 10-11C	4-5C & 11-12C	<4 C >13C
Fry	10-15 C	8-10 C & 15-16 C	4-6 C & 16-17 C	<4 C & >17 C
Juvenile	10-15 C	8-10 C & 15-16 C	4-6 C & 16-17 C	<4 C & >17 C
Smolt	8-12 C	6-8 C & 13-14 C	4-6 C & 15-16 C	<4 C & >16 C
Adult	10-13 C	8-10 C & 13-15 C	4-8 C & 15-16 C	<4 & >16 C

Floodplain Connectivity: The USFS (2000) Region 5 watershed condition rating system is aimed at maintaining "the long-term integrity of watersheds and aquatic systems on lands the agency manages." Scores are based on both quantitative data and professional judgment by the staff having decades of experience as professional biologists. These criteria have substantial commonality with other regional Pacific salmon habitat assessment methods (USFS, 1995; Spence et al., 1996).

The USFS considers channel condition to be Properly Functioning when more than 80 percent of the low gradient response reaches have floodplain connectivity, while 50-80 percent was considered Partially Functional and less than 50 percent Non-Functional. Since there are only three categories, values will be adapted to the CAP as follows: Impaired = Poor, Partially Functioning = Fair and Fully Functional = Very Good.

Flow: The Southwest Oregon Province Partnership (SWOP) project is a cooperative assemblage of geographic information (GIS) data for aquatic and watershed condition assessment. ODFW contributed data regarding priorities for restoring flow:

> "The Streamflow Restoration Priorities have been identified by small or large sub-basin areas for all systems on the Oregon coast, to identify the need for recovering streamflow from consumptive users, aimed at 'reversing' the identified 'factor for decline' of water quantity loss. There is no current write-up of the methods used, but it was a numerical ranking method, based on about a dozen fish resource and habitat parameters, and several water use factors."

ODFW flow restoration priority data for southwestern Oregon are displayed in Figure 2 along with water diversion information. Although the streamflow restoration priority database was not explicitly built for limiting factors assessment, there is a high concentration of stream diversions within sub-basins ranked as High Priority for flow restoration.

The USFS (2000) Region 5 watershed assessment provided professional judgment ranking of water quantity and flow regime, according Properly Functioning status to streams with unaltered flows, Partially Functioning status to streams where base flows and peak flows are unaltered but "mid-range discharges may impair aquatic habitat availability, and Non-Functioning to streams with "peak flows and low flows significantly departing from a natural hydrograph" and "resulting in changes to channel morphology." Ranking is similar to that described above for channel connectivity.

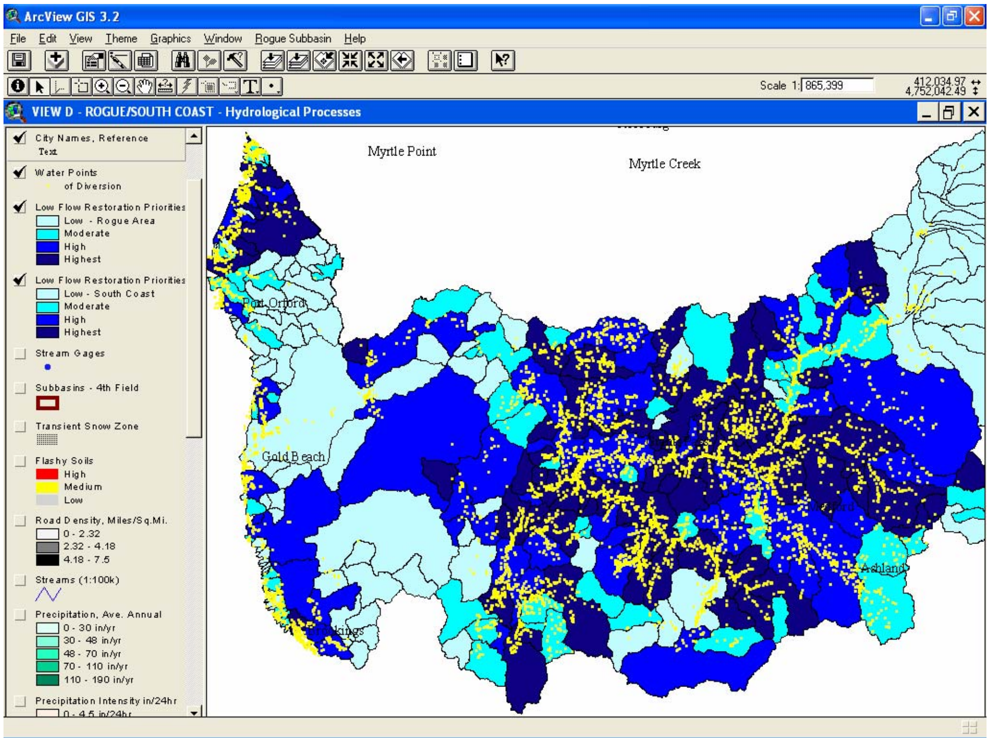

Figure 2. ODFW priorities for flow restoration and water diversions in southwest Oregon. Taken from SWOP project.

THREATS AND SOURCES OF STRESS

> "Aquatic habitats critical to salmonids are the product of processes acting throughout watersheds and particularly within riparian areas along streams and rivers….Salmonid conservation can be achieved only by maintaining and restoring these processes and their natural rates." (Spence et al., 1996)

Reference values for the SONCC CAP, presented below for threats to salmonid habitat (Threats) or upland disturbance stress sources (Sources) are not regulatory targets. They should be considered indices of risk associated with the pattern and extent of watershed disturbance and land use activities. The further the flow regime, range of forest age, the amount of compacted watershed area or exposed soil areas are from the historic or normal range of variability, the greater the likelihood of negative impacts to coho salmon habitat (Spence et al., 1996).

There are some potentially critical Threats/Sources for which there are no data or for which data are sparse or methods of survey are different and non-comparable across the region. Some discussion of the use of professional judgment in the assessment of these in the CAP follows, however systematic methods to devise some ratings of such data are still under consideration. Table 5 contains a summary of references for Threats/Sources values used to shape summary values in the SONCC CAP database and a discussion of their scientific basis then follows.

Table 4. Threats and Sources of Stress references used in the SONCC CAP database.

Threat/Source	Low	Medium	High	Very High
Timber Harvest	<10%	10-25%	25-35%	>35%
Agriculture	<2%	2-5%	5-10%	>10%
Road Density (mi/sq mi)	<1.6	1.6-2.5	2.5-3.0	>3.0
Total Impervious Area (TIA)	<5%	5-10%	10-25%	>25%

Timber Harvest: The Oregon and California portions of the SONCC are comprised mostly of forested watersheds and logging is recognized as a major Threat/Source. Spence et al. (1996) described the effects of timber harvest on salmonids as follows:

> "Riparian logging depletes large woody debris (LWD), changes nutrient cycling and disrupts the stream channel. Loss of LWD, combined with alteration of hydrology and sediment transport, reduces complexity of stream micro- and macrohabitats and causes loss of pools and channel sinuosity. These alterations may persist for decades or centuries. Changes in habitat conditions may affect fish assemblages and diversity."

Reeves et al. (1993) studied eight coastal Oregon watersheds and found that those where timber had been harvested more than 25 percent in the previous 30 years had fewer Pacific salmon species, with one species clearly predominating. They also found "streams in basins with low timber harvest had more complex habitat, as manifested by more large pieces of wood per 100 m." Swanson et al. (1998) noted that logging in 20-30 percent of an Oregon Cascade watershed caused catastrophic channel changes with "resulting complex patterns of flood disturbance, interspersed with refuge sites experiencing minor flood effects, substantially influenced by vegetation conditions in watersheds at the time of the flood."

Klein et al. (2008) studied the relationship of timber harvest rate and turbidity levels that would limit steelhead juvenile growth and recruitment to adulthood aand concluded that "average annual harvest rates greater than about 1.5% (representing a 67-year rotation cycle) should be avoided" in northwestern California coastal watersheds. This estimate is recognized as conservative because the lower bound lines were used in their model instead of the line of best fit from turbidity and harvest rate regressions.

Spence et al. (1996) cited studies by McCammon (1993) and Satterland and Adams (1992) showing increased peak flows resulting from alteration of 15-30% of a watershed's vegetation and concluded "that no more than 15-20% of a watershed should be in a hydrologically immature state at any given time." CAP references for timber harvest are less than 10% = Low, 10-25% = Moderate, 26-35% = High and >35% = Very High.

Data for coastal watersheds in the California portion of the SONCC from the California Department of Forestry (CDF) cover only private lands, so timber harvests are currently under-estimated in the CAP California for areas with USFS ownership. This could be improved in the future by including federal timber harvest information. CBI (Bredensteiner et al., 2003) compared 1972 and 1992 Landsat imagery to map forest change in southwestern Oregon. These data are used to gauge timber harvest impacts from the Oregon portion of the SONCC. Although this assessment is somewhat out of date, no GIS data on timber harvest from the Oregon Department of Forestry are currently available.

CDF also provides improved road layers for some portion of the SONCC in California associated with updating its timber harvest review process. Timber harvest in terrain subject to rain-on-snow events and shallow land-sliding may trigger cumulative effects (Dunne et al., 2001), but an overlay of high risk areas and land management was beyond the scope of the SONCC CAP project.

<u>Agriculture</u>: Irrigated agriculture and livestock grazing can negatively impact coho salmon habitat (Nehlsen et al., 1991). The extent of agricultural land use can be assessed using 2001 Landsat data as interpreted by the Multi-Resolution Land Characteristics (MRLC) Consortium (Homer et al., 2004). The CAP uses the combination of two land use categories to represent agriculture: Pasture/Hay and Cultivated Crops. The Grassland/Herbaceous category was not used, as there is no way to know whether such lands are grazed. The preliminary rating within the CAP is based on the percentage of watershed area that is being used for agricultural activities. A frequency distribution of SONCC Landsat data was used to rate agricultural impacts with <2% = Low, 2-5% = Medium, 5-10% = High and >10% = Very High.

<u>Road Density</u>: Armentrout et al. (1999) used a reference of 2.5 mi./sq. mi. of roads as a watershed management objective to maintain hydrologic integrity in Lassen National Forest watersheds harboring anadromous fish. Regional studies from the interior Columbia River basin (USFS, 1996) show that bull trout do not occur in watersheds with more than 1.7 miles of road per square mile.

The road density ranking system shown in Figure 3 was developed based on the Columbia basin findings. NMFS (1995) required that road mileage be reduced with an emphasis on "road closure, obliteration, and re-vegetation." where road densities exceed two miles per square mile on USFS and BLM land in the interior Columbia River basin in order to protect Pacific salmon species.

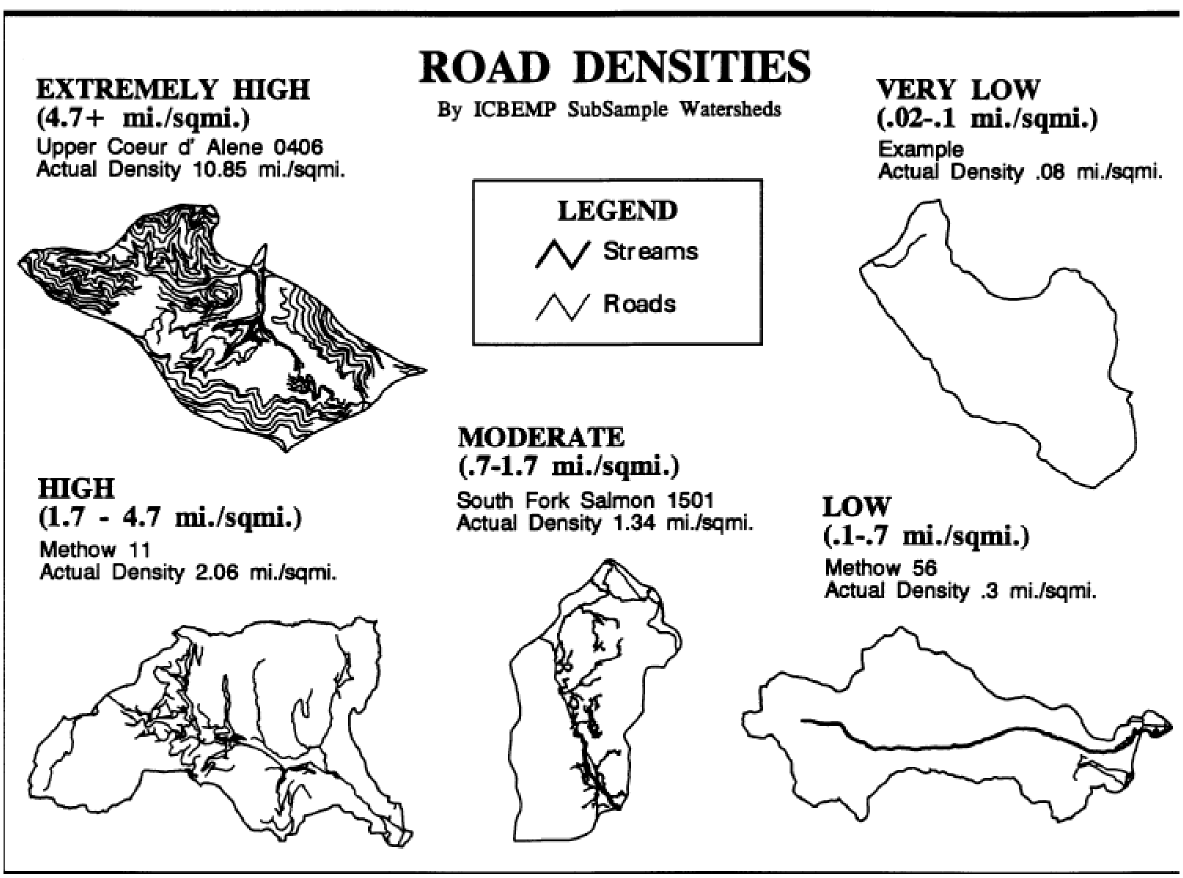

Figure 3. Graphic from Interior Columbia Basin Management Plan (USFS, 1996).

Cedarholm et al. (1980) found that fine sediment in salmon spawning gravels increased by 2.6 - 4.3 times in watersheds with more than 4.1 miles of roads per square mile of land area. Matthews (1999) linked increased road densities to increased sediment yield in the Noyo River. The National Marine Fisheries Service (1996) guidelines for salmon habitat characterize watersheds with road densities greater than three miles of road per square mile of watershed area (mi/sq mi) as "not properly functioning" while "properly functioning condition" was defined as less than or equal to two miles per square mile, with few or no streamside roads.

For Oregon, the SONCC CAP uses road densities calculated by CBI using BLM 1:24,000 scale roads. For coastal areas of California, road densities were calculated using roads included in CDF timber harvest GIS data. For inland areas, road densities were calculated using a roads theme produced by Legacy—The Landscape Connection which uses multiple sources. Road density data from the SWOP GIS project and USFS (2000) Region 5 were also considered, but these data were older than the CBI, CDF, and Legacy datasets and were not, therefore, used.

CAP references for road densities, then, reflect the studies above: <1.6 mi/sq mi = Very Good, 1.6-2.5 mi/sq mi = Good, 2.5-3.0 mi/sq mi = Fair and >3.0 mi/sq mi = Poor. Road density scores are applied to the attributes Hydrologic Function and Sediment Supply within the CAP. CBI uses lower thresholds for road densities in scoring watershed health based on frequency distributions (Bredensteiner et al., 2003; Bredensteiner and Strittholt, 2004).

Total Impervious Area (Urban, Residential & Industrial Development): Urban and suburban developments cause profound changes to natural watershed conditions by altering the terrain, modifying the vegetation and soil characteristics, and introducing pavement, buildings, drainage, and flood control infrastructure (Spence et al., 1996). Reported impacts include increased frequency of flooding and peak flow volumes, decreased base flow, increased sediment loadings, changes in stream morphology, increased organic and inorganic loadings, increased stream temperature, and loss of aquatic/riparian habitat (May et al, 1996).

The magnitude of peak flow and pollution increases with total impervious area (TIA) (e.g. rooftops, streets, parking lots, sidewalks, etc.). Spence et al. (1996) recognized that channel damage from urbanization is clearly recognizable when TIA exceeds 10%. Reduced fish abundance, fish habitat quality and macroinvertebrate diversity with TIA levels from 7-12% (Klein, 1979; Shaver et al., 1995). May et al. (1996) showed almost a complete simplification of stream channels as TIA approached 30% and measured substantially increased levels of toxic stormwater runoff in watersheds with greater than 40% TIA.

The SONCC CAP uses TIA as its reference value for urban, residential and industrial impacts because the metrics derived from Homer et al. (2003) for these categories individually all were partially based on TIA. The primary assessment tool is classified 2001 Landsat imagery for the SONCC provided by the Multi-Resolution Land Characteristics (MRLC) Consortium (Homer et al., 2004). Thresholds for TIA are based on May et al. (1996) and Spence et al. (1996) with <5% = Low, 5-10%= Medium, 10-25% = High, and >25% = Very High. TIA will effect the scoring of attributes Hydrologic Function and Floodplain and Channel Structure.

Other Threats/Sources Considered

Several other threats/sources were considered for inclusion in the SONCC CAP, but were not included in the first version due to lack of data and to time constraints. These threats/sources include: Upland Vegetation Type/Tree Size, Riparian Vegetation/Tree Size, Near-Stream Roads, Wildfire, Rain-on-Snow, Landslide Risk, and Unstable Soil Types. Future versions of the SONCC CAP may include these threats/sources, for that reason, they are discussed here:

Upland Vegetation Type/Tree Size

Classified 1999 Landsat imagery processed by the U.S. Forest Service and the California Department of Forestry is available for the SONCC (Warbington et al., 1998). These data can be used to assess seral stage and potential deviation from the natural range of variability capable of elevating the risk of increased peak flows. Tree size and vegetation type Landsat data could have been used where timber harvest data were not available, but this level of analysis was not practical in the current project.

The suggested SONCC CAP reference values for seral stage are based on Reeves et al. (1993), Swanston et al. (1998), McCammon (1993) and Satterland and Adams (1992). Watersheds having greater than 30% of their area in early seral conditions (<12" dbh) are Poor and less than 10% in early seral conditions as Very Good. If applied to the geographic area of the SONCC CAP, areas that should be excluded from consideration are natural grasslands in Central Belt Franciscan terrain, bare rock or areas above the timberline and Serpentine soils in the Klamath Mountain Province.

CDF and the USFS Spatial Analysis Lab also collaborate on "change scene detection" projects, which compare two sets of Landsat images (Fischer, 2003). This kind of data is available for the California portion of the SONCC with Landsat images from 1994 and 1998 used for comparison.

These data are useful for analysis of timber harvest, fire or other rapid land conversion, but are beyond the scope of this SONCC CAP project.

Riparian Vegetation/Tree Size

Spence et al. (1996) recognized the distance equal to the potential height of riparian trees (one site potential tree height) as a minimum buffer to allow for recruitment of large wood to Pacific salmon streams. FEMAT (1993) extended that zone of influence to two site potential tree heights or to the top of any inner gorge areas. The 100 meter buffer which could be selected for the CAP is approximately equivalent to two site potential tree heights in old growth Douglas fir or Sitka spruce forests or 1 ½ site potential tree heights in mature redwoods. Spence et al. (1996) suggested 200-240 as an appropriate site potential tree height for redwoods.

The resolution of Landsat data are one hectare and CAP scoring would have been based on average basal diameter. Beardsley et al. (1996) used a diameter of 40" as indicative of old growth forests in the Sierra Nevada and the diameter of coastal riparian redwoods before disturbance may often have been several feet in diameter (Noss et al., 2003). The CAP ratings would have utilized 20" in diameter because trees of this diameter represent at least mid-seral coniferous trees that can contribute long lasting large wood as well as provide other riparian functions.

Riparian zones with 80% of their trees having a diameter at breast height (dbh) of 20 inches or greater should be rated as Very Good. If less than 50% of trees in a riparian zone are less than 20 inches dbh, the CAP reference should be Poor. The latter condition equates with reduced buffer functions and lack of potential large wood recruitment. Both the SWOP and CBI have data of this type that was evaluated for use in the CAP, but use proved infeasible with current resources.

Near-Stream Roads

Roads constructed within the riparian buffer zone pose many risks to coho salmon habitat including the loss of shade, decreased large wood recruitment, delivery of fine sediment and initiation of mass wasting (Spence et al., 1996). Rock revetments are often used to prevent streams from eroding road beds, resulting in channel confinement that can lead to incision of the stream bed. The USFS (2000) provides data for near stream roads in road miles per square mile and a frequency distribution was used to derive values showing very low relative risk as Very Good (<0.1 mi/sq mi) and the opposite end of the frequency spectrum as posing high relative risk to adjacent coho habitat as Poor (>1 mi/sq mi). Unfortunately, use of non-standard watersheds made it infeasible to assimilate data for this phase of the SONCC CAP project.

The Freshwater Creek CAP pilot used existing road and stream data to calculate associations using road densities within the 100 m of streams. This riparian zone of influence was calculated as road miles in the buffer per square miles of watershed area with the following reference values: Low = <0.1 mi/sq mi, 0.1-0.5 mi./sq mi. = Medium, 0.5-1 mi/sq mi = High, and >1 mi/sq mi = Very High. These Threat/Source values were applied to the attributes Floodplain and Channel Structure, Riparian Conditions and Water Quality. If there are sufficient resources available to future CAP applications in the SONCC this statistic would be useful.

Wildfire

The interior areas of the SONCC may have significant fire risk with potential for watershed disturbance and increased sediment yield. Coastal ecosystems have higher rainfall, less extreme summer air temperatures and, therefore, less risk of catastrophic fire.

Spence et al. (1996) recognize that the extent of watershed damage and risk to salmonid habitat is directly related to the intensity of the burn. Hotter fires consume organic matter that binds soils, leading to an increase in erosion potential, or in the worst case can volatilize minerals in the soil causing it to become hydrophobic. Obtaining detailed, current fire data that reflects intensity of burns from the many different entities with fire data within the SONCC was beyond the scope of this project, but discussions on classifying fire risk to aquatic ecosystems in the SONCC are still presented because they have potential future application, as more CAP projects are carried out in Pacific salmon watersheds.

High humidity in riparian zones usually prevents high intensity fires near streams, but hot riparian fires can reduce large wood recruitment and increase water temperatures as a result of canopy removal (Spence et al., 1996). CAP references derived from fire data would use only high intensity burns. Thresholds for disturbance recognized as likely to trigger changes in peak flow or sediment yield might be similar to those discussed under Timber Harvest above. Overlap of burns with areas of high landslide risk could be discerned from existing data (See SHALSTAB discussion below).

Rain-on-Snow Events

Changes in hydrologic response to the removal of large-tree land cover and road building varies with elevation. Areas within the transient snow zone (3500-5000) may accumulate snowfall in clearcut or newly burned areas that would otherwise be caught in the canopy and partially dissipated back into the atmosphere through ablation. Berris and Harr (1987) noted substantial increased peak discharge in the Oregon Cascade streams below areas of extensive clear-cutting in the transient snow zone. Jones and Grant (1996) found that roads extended stream networks, increasing peak discharge, with even greater risk at elevations susceptible to rain-on-snow.

It was decided that the inherent risk of rain on snow derived from just elevation data was not useful in determining risk to coho salmon habitat in the SONCC. Future CAP projects might consider quantifying associations with timber harvest, high intensity fires and road networks in the transient snow zone. The SWOP project provided a theme on the rain-on-snow zone in the Oregon portion of the SONCC and 10 meter digital elevation model (DEM) data could be used to delineate one in California SONCC watersheds.

Landslide Risk

Montgomery and Dietrich (1994) used steepness and concentration of water flow to predict the risk of shallow debris sliding with a model referred to as SHALSTAB. This model is very useful as a reconnaissance tool for understanding risk of landslides related to timber harvest or other land use, but should not be relied on as the sole basis for land use decisions. As with rain-on-snow potential, knowing the area with high landslide risk was not considered useful in assessing risk to coho habitat. Future CAP applications in similar Pacific salmon watersheds might consider quantifying overlap of land use activities and high intensity fire with high risk landslide zones (SHALSTAB score of 2.8 or greater).
Kier Associates (2005) demonstrated that 80% of landslides that occurred in the lower west side Scott River Basin resulting from the January 1997 storm were in zones classified as extreme risk, using SHALSTAB (Montgomery and Dietrich, 1994).

Unstable Soil Types

Some underlying bedrock parent materials in the SONCC give rise to very unstable soil types, such as decomposed granitic soils (Sommarstrom et al., 1990). Data on watersheds with unstable soils for the Oregon portion of the SONCC were provided by the SWOP, but metadata were not sufficient for application in the SONCC CAP. Electronic GIS soils data were not available for the California portion of the SONCC. Again the most useful query, were high quality soils data available, would be the overlap of management and the most erodible soil types.

SONCC CAP ONLY ONE TOOL IN THE RECOVERY PLAN DEVELOPMENT

The SONCC CAP application provides important insight for NMFS staff and a powerful summary presentation for each coho population in the recovery plan under development. Because data for Indicators and Threats/Sources of Stress in the CAP are not complete, NMFS Arcata staff will use additional tools to assess coho population or habitat impacts on a case by case basis. There is a considerable amount of data available that applies to local areas only and, was therefore impractical to integrate into the CAP. These detailed data, high resolution ortho-photos and dozens of GIS themes will help create a more detailed picture of each population and how they can be restored as the SONCC recovery plan is developed.

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