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Plum Creek Timber Company
Native Fish Habitat Conservation Plan

SYNTHESIS OF WATERSHED ANALYSIS AND ECOCLASSIFICATION AT A RIVER BASIN SCALE FOR THE CONSERVATION AND MANAGEMENT OF AQUATIC ECOSYSTEMS

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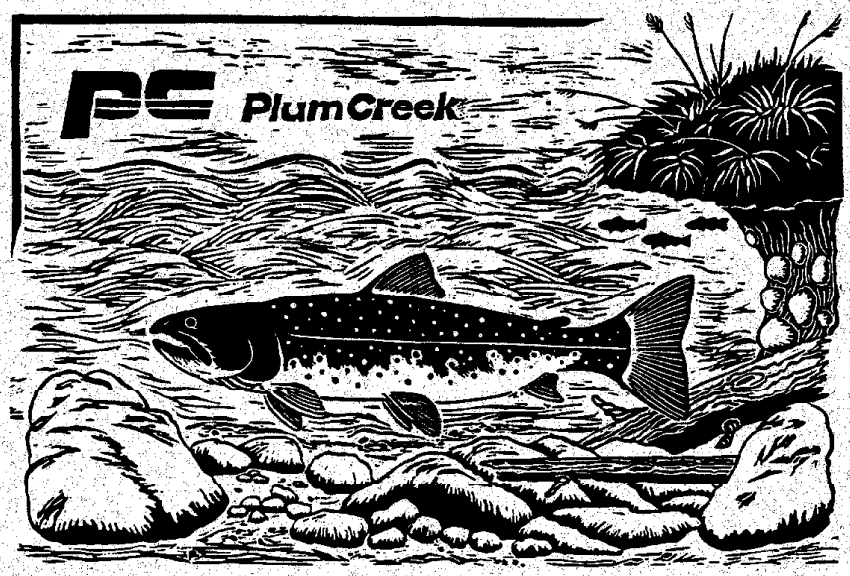

PlumCreek

SYNTHESIS OF WATERSHED ANALYSIS AND ECOCLASSIFICATION AT A RIVER BASIN SCALE FOR THE CONSERVATION AND MANAGEMENT OF AQUATIC ECOSYSTEMS

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ABSTRACT

This work is based on the premise that geomorphic variables tend to predictably replicate and pattern as dictated by larger scale physiographic variables such as parent geology, erosional processes, drainage area, and climate patterns. We hypothsized that a combination of physiographic factors that can be extracted at relatively large scales (e.g. soils maps, 7.5 minute quads, aerial photos) can be used to predict finer scale geomorphic patterns that are not only effective at predicting the distribution/segregation of fish populations, but also at predicting the various elements differentially contributing to channel archetecture and the relative sensitivities to upland land management practices.

We used GIS layers of large scale physical watershed characteristics to develop an ecoclassification of aquatic habitats based on parent geology, landtype associations, valley bottom geomorphology, and stream order. This classification resulted in the delineation of several "geomorphic guilds". A stratified sampling strategy was developed and implemented to test the hypothesis that physical fish habitat characteristics and fish population assemblages would be more similar within respective channel segments of a specific guild than in channel segments represented by other guilds. Concurrently, we conducted intensive watershed analysis in subbasins containing representative channel segments of all guilds in order to discern cause-effect relationships of land management activities upon habitat characteristics, and to determine the relative sensitivity of respective guilds to potential changes in input processes (wood, flow regime, sediment, shade). These two processes allow for the clustering of geomorphic guilds from two perspectives: importance to fish populations, and vulnerability to upland land management activities.

The clusters of geomorphic guilds can then be extrapolated (using GIS) across the study area so as to provide a large-scale management tool allowing for enhanced ability and confidence in the protection of aquatic resources. We feel that this scientifically-based approach of extrapolating watershed analysis findings is superior to the approach of developing questionable thresholds based on empirical data generated from locales exhibiting potentially dissimilar pattens in geology, precipitation, and vegetation.

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1. INTRODUCTION

Various approaches have been implemented to mitigate the potential impacts of forest practices upon fish habitat and water quality. Virtually all states in the Pacific northwest have promulgated regulations requiring both the retention of riparian buffer zones and specific performance standards, known as Best Management Practices (BMPs), for the construction and maintenance of forest roads (Ellefson and Cheng 1995). Federal land management agencies have also advocated the retention of riparian buffer zones through a variety of management decision documents known as FEMAT (Thomas and Raphael 1993), PACFISH (USDA Forest Service and USDI Bureau of Land Management 1995), and INFISH (USDA Forest Service 1995). The federal approaches generally require buffer zones that are much wider than those required by state regulatory agencies. Additionally, state laws generally allow some level of timber harvest within buffer zones whereas federal rules commonly prohibit activities in these areas unless a variety of parameters conform to a set of thresholds, thought to describe "healthy" aquatic habitat conditions. Refer to Sugden and Light (1998) for a more complete discussion of these state and federal regulatory and management mechanisms.

The federal and state strategies rely on fixed buffer widths that may not to account for the full range of dynamic factors that vary for different stream segments. Factors such as channel migration zones, floodplain width, channel size and slope, large woody debris recruitment processes, and riparian vegetative community structure all play an important role in defining the relative influence of the riparian community upon the physical and biological attributes of a stream channel. Relatively wide fixed riparian buffer widths are likely to account for these variable factors across an array of landscape conditions. Buffers that are too small to "fit" a stream channel and its valley bottom may degrade channel and habitat conditions by altering the supply of riparian inputs, such as shade, woody debris, litterfall, etc. Buffers that are larger than necessary are likely to deprive landowners and resource dependent communities of the economic benefits that could be realized through active silvicultural management of the surplus buffer area unnecessary for maintaining the integrity of the aquatic ecosystem. Another criticism of overly-large no-entry fixed buffers is that they preclude silvicultural management for the purposes of disease control and/or the reduction of fire risk. Hence, in any stream setting, fixed buffers may be viewed as inadequate from either an ecological or an economic perspective. Lastly, there are weaknesses in the approach of using fixed habitat targets for determining an acceptable degree of silvicultural management. This target approach, commonly used in the federal strategies, fails to recognize the inherent variability of target parameters across the variety of stream channel types likely to be encountered. Streams flow through a wide range of climatic regimes, geologies, vegetative communities, and landforms. Any and all of these factors can conspire, at various scales, to influence potential stream and habitat characteristics. Hence, habitat targets may not be achieved within the range of the undisturbed, natural potential of many streams. Conversely, other streams may express higher natural potential than the targets. Thus, although regulatory targets are relatively easy to administer for regulatory compliance, they vastly over-simplify the

structure and variability of streams, and are likely to prove inadequate from a scientific perspective.

Several approaches have been developed that fine-tune management to fit local conditions. One such approach is known as *watershed analysis.* The process of watershed analysis has been used in many areas of the Pacific northwest as an alternative approach to the fixed buffer, threshold-based strategies. Of the various watershed analysis methodologies available, the procedure developed and used by the state of Washington is commonly regarded as the most rigorous and effective procedure (Washington Forest Practices Board 1995). The Washington methodology (level II) requires an extensive analysis of both the existing and potential resource conditions within a drainage area, and enables analysts to define the array of cause-and-effect processes that have the potential to impact fish habitat and water quality. These processes are spatially referenced to landscape features and are linked to specific triggering mechanisms, either natural or management-induced. This process-based approach supports the development of site-specific and generalized management prescriptions that account for both resource conditions and spatial and geomorphic variability within the analysis area. Watershed analysis also provides managers with an assessment of the potential risk of any given activity within a specific area, which allows for the development of appropriate mitigative or preventative management options. Hence, economically feasible resource management can be realized concurrent with scientifically defensible protection and conservation of public resources. Even though this procedure is effective at minimizing risk to natural resources and accounting for the temporal and spatial variation of landscape processes (Cundy and Shult 1998, Toth 1995, Washington Forest Practices Board 1995), the required commitment of funds and personnel is substantial.

When performed repeatedly across similar landscapes, watershed analyses begin to produce some common themes that likely can be applied beyond the specific analysis areas with a high level of confidence. A cost effective conservation strategy will apply resources to additional implementation on-the-ground, rather than additional analyses, once investigations have produced sufficient confidence. In this study, we propose an approach that minimizes risk through the analytical procedures of watershed analysis, while, at the same time, minimizes the financial commitment necessary to confidently protect fish habitat over a large area exhibiting a diversity of channel types, landforms, and vegetative communities. Our work is based on the premise that geomorphic processes are the primary determinants of stream channel structure and function. Geomorphic processes and elements are predicted by patterns of larger-scale physiographic variables, such as parent geology, erosional processes, drainage area, and climate patterns. The distribution of aquatic organisms is associated with those patterns of geomorphic elements (Lotspeich 1980). We tested the hypothesis that a Geographic Information System (GIS)-based hierarchical ecoclassification can be used to delineate groups of channel segments that exhibit similar characteristics in terms of fish habitat, fish distribution, and sensitivity to land management activities. Hereafter we refer to these groups of similar stream channels as *geomorphic guilds*. We also hypothesized that these geomorphic guilds can be used as a

template for the extrapolation of the results of watershed analysis (conducted in a subsample of the analysis area) so as to provide for the effective protection of aquatic resources over a large area.

The hypothesis that geomorphically segregated classes of stream channels will influence both the distribution of, and utilization by, various aquatic species is founded on the results of several studies. Nelson et al. (1992) demonstrated that trout distributions at specific sites in northeastern Nevada were clearly related to the patterns of geologic districts and landtype associations. Richards et al. (1996) found that geologic and land-use variables in central Michigan had similar magnitudes of influence on stream habitats that, in turn, influenced macroinvertebrate assemblages. From a study in the upper Snake River basin, Maret et al. (1997) stated that "major environmental factors determining species distributions...were stream gradient, watershed size, conductivity, and the percentage of the watershed covered by forest." Kruse et al. (1997) found that channel slope, elevation, and stream size significantly influenced the distribution of Yellowstone cutthroat trout in the Absaroka Mountains of Wyoming. In another study from Wyoming, Kozel et al. (1989) indicated that differing classes of channel gradient exhibited significantly different habitat features and standing stocks of trout. Leathe and Enk (1985) found that fish distribution in the Swan River basin was strongly influenced by channel gradient, in that brook trout were most abundant in lower gradient reaches while cutthroat trout predominated in the higher gradient reaches, and bull trout were most abundant in reaches less than six percent gradient. Leathe and Enk (1985) also indicated that bull trout abundance was positively correlated with drainage area and substrate, while high cutthroat trout densities were most often found in small streams. Watson and Hillman (1997) found that bull trout distribution throughout a large portion of the Pacific northwest was strongly influenced by the availability of certain valley bottom types in tributary watersheds. Rieman and McIntyre (1995) also demonstrated that watershed size and stream width were important factors explaining the occurrence of bull trout.

The influence of geology, landform, and other large scale physiographic factors upon physical channel structure and the relative importance of habitat forming factors has also been documented in many studies. Benda et al. (1992) suggested that the nature of stream habitats is strongly influenced by geomorphic setting since they found that the distribution of habitat types was related to glacial history and the spatial distribution of different glacial deposits such as moraines and lens of lacustrine clay. Richmond and Fausch (1995) documented how the character and function of large woody debris (LWD) varies with channel size in northern Colorado. The found that the function of LWD in forming fish habitat was strongly influenced by the stream's location in the watershed, and that stream size and gradient exerted significant influence on the characteristics and function of LWD in the studied streams. Montgomery et al. (1995) sought to demonstrate that the effect of LWD on the abundance of pools is a function of channel morphology, defined largely on the basis of slope class. This study examined relatively low-gradient (primarily < 6% slope), mountain streams in western Washington and southeast Alaska with both logged and unlogged riparian forest. Their data showed that LWD abundance

had a more pronounced effect on pool abundance in channels with intermediate slopes, with less effect at the lowest slopes and the highest slopes. A predictive relationship was developed between pool spacing per unit channel width and LWD frequency per unit channel length. Beechie and Sibley (1997) reported similar findings, but also showed how size of pool-forming LWD increased with increasing channel width. Their analysis indicated that low-slope channels are less sensitive to LWD abundance (as opposed to moderate slope channels) because pools are formed by mechanisms other than LWD when LWD abundance is low. The also found that percent gravel was best explained by channel slope and channel width, and that there was no significant relationship between LWD and percent gravel. Myers and Swanson (1996) indicated that stream type affected the rate at which streams responded to grazing improvements. They indicate that the observed change of pool variables and width/depth ration was directly influenced by channel gradient and entrenchment. Montgomery and Buffington (1997) presented a hypothesis with supporting data that channel classes for mountain streams, based primarily on channel slope, exhibit consistent morphology (e.g. pool frequency, channel cross-section and planform shape, resistance to flow). They further hypothesized, based on principles of fluvial geomorphology, how different channel classes would be expected to respond differently to changes in inputs of sediment, wood, and stream flow. Benda and Dunne (1997) developed a model of mountain channel networks for coastal Oregon and used it to demonstrate how mass wasting processes, forced by long-term fire and storm frequency, control the spatial and temporal distribution of sediment transport and storage in stream channel networks, with implications for spatial-temporal variation in fish habitat. Their work suggests that higher order, low gradient channels exhibit low intensity, chronic sediment fluxes while lower order, high gradient are subject to episodic disturbances of high magnitude. A common theme exhibited by all these studies is that the geomorphic setting of any given stream channel will ultimately determine the extent and magnitude of potential impact caused by anthropogenic and natural disturbances (i.e. modification of fluxes of LWD, sediment, and discharge).

We propose an ecoclassification approach that captures the attributes of drainage area and stream size, valley bottom slope, dominant substrate, principal riparian vegetative community type, and hierarchically-derived classes of lithology and landform. Although several authors have proposed and described hierarchical aquatic ecoclassifications (Lotspeich and Platts 1982, Imhoff et al. 1996, Frissell et al. 1986, Pojar et al. 1987, Montgomery and Buffington 1993), we are unaware of any studies that have empirically tested the accuracy of an ecoclassification scheme as it applies to the characterization of physical variates and dependent biota. We are also unaware of any frameworks developed for the explicit application of said ecoclassifications for the purpose of guiding on-the-ground land management decisions. This report presents results of our attempts to do both.

2. PROCESS DESCRIPTION

Figure 1a displays a flowchart depicting the conceptual approach we developed for this study.

Our intent was to conduct two separate but complementary analytical procedures to segregate, and then combine, stream channel segments into functionally similar groups exhibiting similar fish habitat attributes, fish population assemblages, and sensitivities to fluxes of upland inputs (from both natural and human-caused disturbances). The first approach involved delineation of unique groups of channel segments based on a hierarchical landscape ecoclassification at a river basin scale. Subsequent sampling and rigorous statistical analysis determined if predicted groupings were effective at differentiating between channel characteristics, in terms of fish habitat and fish assemblages. The second approach, watershed analysis, involved an intensive, analytical procedure conducted within subbasins of the analysis area. Watershed analysis segregated channel segments based on observed geomorphic structure and defined habitat attributes, fish use, and channel sensitivities based on those structures. Where these two independent approaches produce complementary results, we integrated the results of the two approaches into a tool for the protection and management of aquatic resources.

The classification system developed in this paper is unusual in that it explicitly integrates geomorphic classification with fish habitat parameters. During development of the channel classes, the geomorphic classification was conducted independently from the biotic/physical classification. They were subsequently reconciled, with the two independent approaches grouping channel segments similarly for the most part, with a few significant ambiguities. The geomorphic classification was based on the system of Montgomery & Buffington (1997), which is regarded by the author's as having some advantages over other systems (e.g. Rosgen 1994). Chief among these is the system's integration of fluvial geomorphic processes with observations of channel morphology and its explicit consideration of the likelihood of channel response to changes in watershed or riparian conditions. The Montgomery & Buffington system was developed concurrent with implementation of watershed analysis as a forest management tool in Washington, and in the experience of the authors, proved to be consistently applicable across landscapes, as well as sufficiently simple to allow for more detailed classification based on differences in hillslope geomorphic processes and the spatial and temporal relationships among channels and sediment sources. A host of watershed analysis projects conducted by three of the authors under the Washington regulatory system for forest practices lend credence to the notion that this type of geomorphic classification can predict, at least in a relative and qualitative sense, the sensitivity of different channel types to changes in watershed inputs of sediment, wood and water. One relevant test of the Montgomery & Buffington classification relating to the effects of wood on pool frequency (Montgomery et. al. 1995), showed distinct differences among three lower-gradient channel types. More comprehensive studies regarding sediment sensitivity have not been published, but have been presented in watershed analysis projects (e.g. South Fork Skokomish River Watershed Analysis, 1997). It is worth noting that the Montgomery & Buffington system is similar in many important respects to other systems, including Rosgen's. The critical difference in the development of guilds in this approach is the integration of geomorphic and biological/physical parameters, not the basis of geomorphic classification. Another advantage of this approach is that since it is GIS-based, it can be used to *predict* the

structure and sensitivities of any channel segment within the study area, as opposed to empirically based classification schemes requiring field reconnaissance by qualified specialists.

Figure 1b displays a flowchart depicting the approach we developed for this study. The procedural framework of our approach precludes the presentation of our work in the formal style of most studies (e.g., methods, results, conclusions). Because most cells of the framework (Figure 1b) involve the presentation of both methods and results, and since subsequent cells are dependent upon results of the previous cells, we incorporated separate sections to describe procedures and findings for each cell. Below we provide a short description of each cell of the framework:

Ecoclassification - conduct hierarchical ecoclassification of river basin.
Guild - identify dominant geomorphic guilds based on the results of ecoclassification.
Sample Guilds - adequately sample biological and physical parameters of channel segments representative of all geomorphic guilds.
Analyze Samples - conduct statistical analysis of variables sampled to test for significant differences among geomorphic guilds.
Cluster to Super Guilds - use cluster analysis to group geomorphic guilds into super guilds based upon similarity/dissimilarity.
ID Subwatersheds - identify subwatershed(s) that contain complexes of channel segments that represent most, or all, geomorphic guilds and landtypes.
Watershed Analysis - conduct watershed analysis in representative sub-watershed(s).
ID Geomorphic Channel Units (GCU's) - identify geomorphic channel units (GCU's) using watershed analysis methodology.
Describe GCU's - describe GCU's in terms of physical habitat and sensitivity.
Compare Super Guilds and GCU's - compare and contrast super guilds to GCU's to test for "overlap" of physical and biological variables. Modify super guild clusters as necessitated by GCU comparison and statistical significance.
Describe Super Guilds - display and discuss super guilds in terms of physical habitat variables and fish assemblages.
Correlative Relationships - assess associations between independent physical variables and dependent biological variables within each super guild.
Vulnerability Matrix - modify GCU sensitivities as necessitated by biological criteria to provide assessment of resource vulnerabilities.
Compare Vulnerabilities to Relationships - compare and contrast GCU vulnerability calls to significant correlative relationships in corresponding super guilds to test for "overlap"of cause-and-effect processes.
ID Surrogates - identify surrogate GCU/super guild combinations where significant overlap exists, define vulnerability matrix for super guilds.
Identify Hazards - identify mechanisms or processes that would likely result in delivered impacts to fish habitat and water quality within specific GCU's from upland land management activities.

Classify Hazards by Landtypes - spatially classify delivered hazards with landtype class template if patterns are found to exist.
Prescriptions - develop specific prescriptions to "minimize" or "prevent and avoid" impact scenarios.
Extrapolate Prescriptions - apply relevant GCU-based prescriptions to surrogate super guild channel segments (vulnerability) and landtypes (delivered hazard) throughout river basin.
Effectiveness Monitoring - evaluate effectiveness of application of prescriptions by monitoring response parameters specific to input processes (e.g., percent surface fines to evaluate sediment delivery from roads) and modify prescriptions as needed.

3. ECOCLASSIFICATION

The goal of this ecological classification was to group landscapes with distinctive form, function and ecological potential and to order these such that relationships between groups can be better understood. The framework consists of hierarchical levels, arranged in sequence from coarse to fine-scale. This approach can be conceptually displayed as follows:

Ecoregion	*Large Scale, General Criteria*
Geologic District	
Section	
Subsections	
Landtype Class/Association	
Landtype	
Habitat Type	
Riparian landtype	*Small Scale, Specific Criteria*

The upper levels (ecoregion, geologic district and subsection) are founded mostly upon causative, independent variables. Ecoregions are based on land-surface form, potential natural vegetation, land use and soil (Omernik 1987); geologic districts are distinguished by lithology and correlate with sections of Wertz and Arnold (1972); subsections (ibid.) are identified by geologic structure and the dominant geomorphic processes expressed by the landscape. The lower levels (landtype class/association, landtype, habitat type and riparian landtype) are based, successively, more upon manifest and dependent variables. The focus of landtype classes and landtypes was habitat types distinguished by position, soil and biotic productivity. Riparian landtypes were distinguished by valley-bottom gradient, size of dominant streambed materials, and dominant vegetation community (Sirucek and Bachurski 1995).

Hierarchical levels may also be thought of as layers of information, the concept on which GIS mapping is based. The top layers (e.g., ecoregion) consist of large polygons that are described in terms of general criteria. At successively lower levels, polygons are divided into smaller areas according to more refined criteria, which allow increasingly specific interpretations. The

classification is applied from the top level down and thus accounts for variance at the broadest level. The various scales used in the classification allow interpretation and generalization at perspectives ranging from regional to local and specific. Information from lower levels can also support generalizations at higher levels.

Ecoregions were based on digital map files obtained from Omernik (1987). Geologic district was based on the distribution of rock types digitized from 1:250,000 scale geologic maps (Mudge et al. 1982). Subsections were distinguished by geologic structure (e.g., scarp versus dip slope) and geomorphic process (e.g., alpine versus continental glaciation). Figure 2 displays the distribution of the three subsections found within the Swan River basin. Landtypes were described in terms of landform, geology, soil, vegetation series (Pfister et al. 1977) and slope. Landtype classes (LTC's) were distinguished by position and landform morphology that are aggregates of landtypes identified by the Martinson and Basko (1983) and from Sirucek (unpublished). These are conceptually similar to landtype associations identified by the Flathead National Forest

Habitat types (Pfister et al. 1977) were identified by Sirucek (1994) for the Flathead National Forest based on empirical models, forest stand data, and forest structural class. Statistical analyses of ECODATA plots served as a basis for the empirical models. Primary parameters for distinguishing habitat types were elevation, slope, aspect, geographical subdivision and landtype.

Most riparian landtypes are inclusions within the previously discussed landtypes and habitat types. For a more complete discussion of this ecological classification, including descriptions of criteria and information used for each element of the classification process, refer to Jensen and Dean 1996) and Jensen et al (1998).

4. GUILD

Geomorphic guilds are combinations of riparian landtype, classes of stream order, and landtype classes. Riparian landtype (RLT; Sirucek and Bachurski 1995) was the primary component used in designating geomorphic guilds. RLT's result from the combination of three distinct valley-bottom features: valley bottom gradient, streambed material size, and potential natural vegetation communities (riparian habitat type). The first two letters of the RLT code denote the valley bottom gradient class (FL = 0 to 2 percent slope; NL = 2 to 4 percent slope; SL = 5 to 12 percent slope; MS = 13 to 39 percent slope; VS = greater than 40 percent slope; WS = undifferentiated slope and denotes springs, wet depressions, and initial portions of stream channels that range from 2 to 45 percent slope). The third digit of the code denotes the size class of dominant streambed materials (1 = clay, silt, fine and medium sand; 2 = coarse sand, gravel, and cobble; 3 = small and large boulders; 4 = bedrock; 5 = undifferentiated streambed materials). The last letter of the code denotes the dominant vegetation community type (A = subalpine fir habitat types; B = grand fir and western redcedar habitat types; C = Engelmann spruce habitat types; D =

black cottonwood habitat types; E = willow and sedge community or habitat types). Figure 3 displays the distribution of RLT's in the Swan River basin. The RLT code is the first element of the geomorphic guild code.

RLT's did not directly differentiate between stream size and/or drainage area. RLT's do differentiate indirectly since steep streams tend to be lower order and lower gradient streams tend to be higher order. However, we found considerable variability in the distribution of stream order for some RLT's. Because we needed to incorporate an attribute that reflected channel size in the geomorphic guild classification, we combined RLT with stream order (Strahler 1957). The distribution of stream order for perennial stream channels, derived at 1:24,000 scale (Jensen and Dean 1996), is displayed in Figure 4. Stream orders were grouped into three classes to reflect general channel size. Hence, first and second order channels were combined into order class 1 (CO1), third and fourth order channels into order class 2 (CO2), and fifth and sixth order channels into order class (CO3). No channels in the study area were larger than sixth order. Stream order class was indicated as the second element of the geomorphic guild code.

An *a-priori* examination of ecoclassification map units indicated that RLT's did not exhibit strict inclusion within specific landtype classes. Since we intended to incorporate landform elements into the geomorphic guild classification scheme, we included landtype class as a final layer. These landtype classes can be indicative of several factors including erosion potential, sediment delivery efficiency, potential for groundwater upwelling, inner gorge formation, and floodplain width. Figure 5 displays the distribution of landtype classes in the Swan River basin. For a more complete description of landtype classes, refer to Jensen and Dean (1996). Landtype class is shown as the final element of the geomorphic guild code, denoted numerically (LTC1 = Lake; LTC2 = Wet Depression; LTC3 = Floodplain; LTC4 = Alluvial Fan; LTC6 = Glacial Basin; LTC7 = Ground Moraine; LTC8 = Glacial Outwash; LTC9 = Colluvial; LTC10 = Rockland; LTC11 = Residual; LTC13 = Glacial Trough).

After guild combinations were identified, we conducted an analysis to identify the dominant geomorphic guilds in the Swan River basin. The cumulative length of all watercourses in the Swan River basin, including lakes and all mapped perennial and intermittent channels, equaled 2,022 kilometers. The cumulative length of all perennial watercourses in the basin equaled 925 kilometers (46% of all watercourses). Since we were interested in fluvial systems we removed lakes from further consideration. Also, since we proposed to investigate relationships between upland land management and fluvial processes, we removed channel segments of RLT FL2D, which is the dominant RLT of the mainstem Swan River, and is exclusively associated with the mainstem (see Figure 3). Vannote et al. (1986) suggested that while the physical structure and ecology of smaller streams is closely associated with adjacent riparian characteristics, large stream systems are relatively disassociated from the immediately surrounding landscape and tend to process and integrate elements from a larger, less intimately associated drainage area. Since our intent was to identify and test the effects of land management upon discrete channel types,

we assumed that any findings in these large mainstem channels would be masked and/or biased by autecology, significant in-channel variation, and the potentially diminished magnitude of management effects (in terms of detecting cause-and-effect processes). The removal of lakes, FL2D channel segments, and small unclassified channels (due to mapping error) resulted in a total length of 765 kilometers, comprised by 80 guilds (combinations of RLT, combined order and landtype class). This represents 83% of all perennial watercourses. Finally, in order to designate "dominant guilds", we elected to investigate those guilds whose cumulative length was greater than 1 % of the total Swan River perennial tributary length (765 kilometers). Hence, dominant guilds represented a total channel length greater than 7.6 kilometers. This filtering analysis resulted in a final suite of 27 dominant geomorphic guilds (Table 1). The cumulative length of all channel segments of all dominant guilds equaled 565.3 kilometers, or 74% of the cumulative length of all perennial tributary guilds classified. Figure 6 shows the aggregate distribution of the 27 dominant geomorphic guilds of the Swan River basin.

5. SAMPLE GUILDS

5.1 Estimates of Sample Size

We used power analysis to estimate the number of independent samples needed to assess differences in fish populations and their habitat among different guild types within the Swan River basin. Because our statistical hypothesis was that there was no difference in fish populations and fish habitat among the independent guild types, we treated this study as a single-factor F-test with several means. As part of power analysis, we estimated Type I errors (α = probability of rejecting a true hypothesis of no difference), within-guild standard deviations (σ = square root of the mean square of error), and effect sizes. We used existing habitat data collected from six different guilds in the Swan River basin to estimate σ. One-way analysis of variance (ANOVA) tested differences in eight habitat variables among the six guild types. We calculated σ as the square root of the mean square of error from the ANOVA summary tables. We used the smallest and largest σ values to calculate sample sizes. We included four effect sizes ($f = 0.10$, 0.25, 0.40, and 0.60) in all calculations. Cohen (1988) indicates that $f = 0.10$, 0.25, and 0.40 represent small, medium, and large effect sizes, respectively. We compared these estimates with observed effect sizes using the habitat data from the six guilds. Following Cohen (1988), we calculated f for each habitat variable as the square root of the quantity of between-guilds degrees of freedom multiplied by the ratio of the F statistic to the total sample size ($f = [df_b(F/N)]^{0.5}$).

Using estimates for σ and f, we calculated statistical power (probability that the test will result in statistical significance) of the F-test with sample sizes (n) that ranged from 2 to 10 per guild. We ran tests for $k = 27$ guilds and $\alpha = 0.05$. For all calculations, we assumed a balanced design (i.e., sample size (n) is equal among all guild types). NCSS Power Analysis and Sample Size program (Hintze 1991) was used to calculate statistical power for each n.

These analyses indicated that five to six sample sites provided 0.67 to 0.79 power at $\alpha = 0.05$ and

f = 0.40. Therefore, we sampled five randomly selected sites within each guild. To ensure independence of samples, when possible, sites of the same guild type were randomly selected from differing tributary watersheds.

5.2 Sampling Protocol

To capture habitat variability and fish species richness, our site lengths varied with mean wetted-stream width (MSW). We used the protocol described in Simonson et al. (1994) to define site lengths for fish population and habitat sampling within guild types. We calculated site length as the product of MSW, transect spacing, and number of transects. Following Simonsen et al. (1994), guild sites with MSW of 1 to 10 m required survey lengths of 39 to 400 m, respectively. However, to be consistent with Watson and Hillman (1997), no survey site was shorter than 100 m. Therefore, sites with a MSW less than 2.56 m were 100 m long. This approach is founded on principles of fluvial geomorphology (e.g., Montgomery and Buffington 1997) and the ecology of stream fish communities. According to Simonson et al. (1994), this approach should capture the natural sequencing of habitat features (e.g., pools, riffles, bends), which tend to repeat at multiples of the stream width, and fish species richness.

Within each sample site, we measured 25 physical habitat variables (Table 2) and estimated fish numbers by species and size class. We accomplished fish population estimates by day snorkeling. Two observers moved upstream through each site and searched carefully throughout all habitat units, including looking under banks and in cover, such as woody debris and rock crevices. This often involved moving or disturbing the cover to locate concealed fish. We then recorded the size and numbers of all salmonids encountered. We divided each fish species into five size-classes, each three inches long, from less than three inches to larger than 12 inches.

We generally followed the procedures outlined in Hillman and Platts (1993) and Watson and Hillman (1997) to describe the physical characteristics of each site. We classified fish habitat units using the level-2 system described by Hawkins et al. (1993). Individual habitat units were defined as an area of the stream with relatively homogenous depth and flow that was bounded by sharp gradients in both depth and flow (turbulent fast water, nonturbulent fast water, scour pool, and dammed pool). A recorded habitat unit had to be equal to or longer than the average width of the wetted channel. Physical habitat measurements are described in Table 2.

Pieces of large woody debris (LWD) were recorded if they were at least 10 cm in diameter, 2 m long, and occurred within the ordinary high water zone of the stream channels, both in the water column and/or within the vertical planes extending up from the banks. In addition to recording the size of all LWD, we noted if LWD functioned to affect the hydraulic properties of the stream channel. LWD function was recorded if the piece caused either pool formation, substrate scour or deposition, or streambank scour or armoring. LWD jams were recorded if they consisted of a conglomeration of two or more pieces of qualifying LWD within the ordinary high water zone. LWD jam dimensions and functions (as above) were recorded as well as the dimensions and sum

of the individual LWD pieces that comprised the jam.

Channel migration zones (CMZ's) were defined as terraces and/or floodplain areas adjacent to stream channels that have a high likelihood of being occupied by the stream channel at some time in the foreseeable future. The Washington Forest Practices Board (1995) defined the channel migration zone as "the area that streams have recently occupied (in the last few years or less often decades), and would reasonably be expected to occupy again in the near future." The maximum potential extent of this zone typically corresponds to the area of "flood prone width" as described by Rosgen (1994). We identified and recorded the extent of the CMZ at four locations at each site, left bank and right bank at 1/3 and 2/3 longitudinal transect length. CMZ boundaries were identified by field evaluation of the combination of relative floodplain and terrace elevations, location of abandoned or high-flow channels, and the lateral extent of the water surface elevation at two times bankfull depth (BFD) (i.e. the flood prone width, per Rosgen 1994).

Because site locations were delineated through random selection and since the study area was historically subjected to both natural and man-caused perturbations, we did not limit our sampling only to "undisturbed sites". To ascertain if disturbance regimes had the potential to skew the data (see Describe Super Guilds), we recorded a disturbance code at each site. We measured riparian vegetative structure (both understory and overstory) for another research study in progress. A site was rated as disturbed if there was observable and measurable evidence that the total riparian stand structure, within 100 feet of both sides of the stream channel, had been altered more than 25% by fire, flood, timber harvest, landslide, grazing, and/or windthrow.

After all of the above variables had been measured and recorded for each site, data were compiled for analysis. Our data matrix consisted of 34 physical habitat variables and 11 fish population variables (Table 3).

6. ANALYZE SAMPLES

We tested the hypothesis that there was no difference in fish population estimates and physical habitat variables among independent guilds within the Swan River basin. Of the 27 guilds in the Swan River basin, we dropped one (WS5A-CO1-LTC7) from further analysis because it contained dry stream channels. We calculated the coefficient of variation (CV = 100·SD/mean) for depths (pool and non-pool habitats) and widths of channel migration zones. We used the CV as a measure of diversity. The CV offers a surrogate for variability because it is independent of the magnitude of the mean. For substrate and embeddedness variables, we calculated the mode and number of levels of the variable that occurred within each site. For example, if the dominant substrate along the length of a stream site ranged from gravel to cobble to boulders, but cobbles occurred most frequently, we calculated the mode as 3 (code for cobble) and the number of levels as three, because three of the six dominant substrate types occurred throughout the site.

Before testing hypotheses, we screened all data for normality assumptions and for patterns of missing values and variance by guild. After screening the data we calculated descriptive statistics (e.g., mean, range, standard deviation, and 95% confidence intervals) for each variable within each guild. Although not all variables met the assumptions of normality or equal variances, we believed the violations were not large enough to compromise the utility of the F-test. However, we used both one-way ANOVA and Kruskal-Wallis one-way ANOVA to assess differences in variable means or medians among the 26 guilds. Only in one case (channel widths per log jam) did the two methods produce different results. For variables that differed significantly among guilds, the Newman-Keuls multiple-comparison test assessed if two or more guilds had mean values that differed significantly from one another. Because we ran 45 ANOVAs, the probability of a Type I error, assuming $\alpha = 0.05$, was $1 - (1 - 0.05)^{45} = 0.901$ (Hays 1988). That is, there was a 90% chance of rejecting a true hypothesis of no difference. To reduce this error, we accepted significance at $\alpha < 0.01$. Results of this analysis are displayed in Table 4. SYSTAT 7.0 and NCSS 97 were used to perform the statistical analyses.

7. CLUSTER TO SUPER GUILDS

ANOVA and Kruskal-Wallis results indicated that variables differed little among some guilds, but greatly among others (Table 4). Thus, we used K-means cluster analysis to group similar guilds, hereafter referred to as *super guilds*. Here our intent was to reduce the total number of guilds into a few clusters with minimal within-cluster sum of squares. We selected the optimum number of clusters (super guilds) as the point where the percentage of variation failed to decrease dramatically as numbers of clusters increased. We then used stepwise multiple discriminant analysis (MDA) to assess which variables were most important statistically in determining differences among super guilds. Before running multivariate procedures, we calculated Pearson correlation matrices to test for multicollinearity among the variables. We used this information to select an array of independent variables for use in cluster analysis and MDA (see Table 3). Variables that did not differ significantly among guilds but did correlate with other significant variables were removed from multivariate analyses. Before we used MDA, we used Box's M to determine if group covariance matrices were equal. SYSTAT 7.0 and NCSS 97 were used to perform the statistical analyses. Cluster analysis resulted in the delineation of 7 super guilds. The results of this cluster analysis are displayed in Table 5.

8. ID SUBWATERSHEDS

Within the Swan River basin, subwatersheds were evaluated for the occurrence of various landtype classes (LTC's) and riparian landtypes (RLT's). That is, for the purpose of conducting intensive watershed analysis, we wished to select watersheds that contained as many LTC's and RLT's as possible so as to maximize our understanding of both the distribution and extent of potential impacts to fish habitat, as well as the relative sensitivities of the geomorphic guilds to changes in input processes. Through this assessment, watersheds sorted into two groups: those

draining the scarp slope of metasedimentary rock in the Swan Mountain range on the east side of the valley, and watersheds draining the dip slope of metasedimentary rock in the Mission Mountain range on the west side of the valley (Figure 2). Scarp slope watersheds were characterized as having steeper slopes and stream channels. Dip slope watersheds are characterized as having more gentle slopes, lower gradient streams, and more lakes (Jensen and Dean 1996). Through this *a-priori* examination, Goat Creek was identified as being largely representative of watersheds draining the scarp slope side of the valley, and Piper Creek was identified as being most representative of watersheds draining the dip slope side of the valley.

9. WATERSHED ANALYSIS

Watershed analysis is a method that combines office- and field-based resource inventories to identify watershed processes that are critical for fish habitat and are sensitive to forest management (Washington Forest Practices Board (WFPB) 1995). A rigorous set of procedures is set forth in a manual organized according to modules that address specific watershed processes (Table 6). The process assesses historic, existing, and potential future forest management impacts on the stream channel network. The channel network is stratified into geomorphic classes with similar conditions and processes. Resource assessment modules are synthesized and integrated by the assessment team. Observed impacts of forest management on stream channels and habitat are located and described. Areas where forest management activities have low, medium or high likelihood of causing a significant impact on stream channel and habitat conditions are mapped. A set of problem statements are developed that specify the nature, location, and extent of forest practices that may adversely affect, and/or have adversely affected, channel conditions and fish habitat in the subject watershed. These "causal mechanism reports" are the basis for developing management "prescriptions" designed to modify or restrict forest management practices to prevent or avoid the identified problems in future forest management operations. The process also inventories areas of degraded habitat where restoration efforts may be warranted.

The following sections describing the results and key findings of the watershed analysis are deliberately concise for the purposes of this paper. For more detailed results and discussion, refer to Watson et al (1996).

10. ID GEOMORPHIC CHANNEL UNITS (GCU's)

The principal objective of the stream channel assessment in watershed analysis is the stratification of stream channel segments into a series of geomorphic channel units or classes (GCU's). The purpose of channel classification is to group stream segments according to channel morphology, habitat potential, and response to potential disturbance and associated changes in watershed inputs. Ultimately, management prescriptions are specified in relation to particular channel classes and their specific vulnerability to habitat degradation.

The geomorphic basis for classifying stream channel segments according to morphology and potential channel response was described by Montgomery and Buffington (1993, 1997). Channel slope is the primary control on channel morphology in this classification system (Table 7). In field applications, channels frequently exhibit more than one of the morphologic types, hence the streams are typically a blend of morphologic types existing along a continuum (Montgomery and Buffington, 1997). In addition, forced morphologies may occur when roughness elements such as large woody debris are introduced to a channel; this may result in deviations in morphology for a typical slope range. Large woody debris recruitment to streams is a complex process that varies significantly in time and space (see Technical Report #7). Channel morphology forced by large woody debris may be a transient condition reflecting localized disturbance of riparian forest stands (e.g. fire or windthrow), that result in a pulse of large woody debris recruitment. The most common forced morphologies are forced pool-riffle and forced step-pool (Montgomery and Buffington, 1997).

The channel classification process begins with preliminary designation of channel segments based on channel slope and confinement classes generated from topographic maps. Subsequent steps include review of historic and current aerial photography to identify types and locations of channel disturbance, and to assess channel confinement. Geologic and soils maps are consulted. Field surveys are then conducted on a sample of representative channel segments. Site selection is quasi-random, and is biased to some degree by accessibility.

Field data were collected to characterize conditions of the channel bed, the active channel, and the floodplain at each survey site. Descriptions of the recommended survey parameters and suggestions regarding their interpretation are given in the watershed analysis manual (WFPB, 1995). For the Swan Valley watershed analysis, an experienced stream channel analyst conducted the stream channel assessment. The survey protocol used was a condensed version of the lengthy and detailed protocol suggested in the WFPB manual. This abridged protocol had been peer-reviewed in the context of prior watershed analyses in Washington. In addition, the channel analyst considered the geomorphic setting of survey sites in the landscape (e.g., proximity to sediment sources, glacier effects), other processes that affect channel morphology or condition (e.g., channel migration, beaver activity), and sensitivity to forest management when developing GCU's. Some GCU's may not be extensively surveyed, particularly if forest management is unlikely to have a significant direct or indirect effect on fish habitat. In these cases, descriptions are based on field observations and data available from maps and other sources.

The riparian function module was also intended to identify areas where changes in stream channel position on the valley floor (channel migration zones (CMZ's)), could cause a standard riparian management zone to be inadequate with respect to long-term LWD recruitment. The frequency and significance of CMZ's in each GCU was evaluated in the stream channel assessment in this watershed analysis project.

11. DESCRIBE GCU's

Based on the stream channel segment map, aerial photo analysis, interpretation of field survey data and other data (e.g., geologic maps), and synthesis with other watershed analysts, channel classes were identified and described. GCU's (called geomorphic map units or GMU's in the WFPB manual) were described in narrative form and supported by data and interpretation. GCU descriptions are not unlike descriptions of soil types found in soil surveys in that they focus on characteristics and processes that typify a GCU while acknowledging substantial local variability. Descriptive characteristics of GCU's developed for the Swan Valley watershed analysis project areas are summarized in Table 8.

After GCU's were defined, the inherent sensitivity of each GCU to watershed inputs and riparian conditions (i.e., management) were described and ranked high, moderate, or low. In this watershed analysis, the physical (non-biological) sensitivity of each GCU was determined by the stream channel analyst. These physical sensitivities are summarized in Table 9. The fish habitat analyst may modify channel sensitivity according to biological criteria; upon review and revision by the fish habitat analyst, channel sensitivities become assessments of resource vulnerability. These vulnerabilities are then compared to delivered hazards identified by other modules in the synthesis process to develop an appropriate management response.

Each of the 13 GCU's is briefly described below. Noteworthy channel sensitivities are also briefly discussed. Figures 7 and 8 display the extent and distribution of each GCU in the subject watersheds.

GCU 1. Swan Floodplain. This minor unit occurs near the confluence of major tributaries with the Swan River in its floodplain. Channel slope is low and substrate is relatively fine owing to the proximity of the mainstem Swan River and consequent backwater effects on tributaries. Channel morphology is pool-riffle.

GCU 2. Entrenched Mainstem. This common channel unit lies on the floor of the Swan Valley topographically above the floodplain of the Swan River. It is entrenched relative to adjacent terrace surfaces; channels nevertheless have the capacity to migrate within their the modern floodplain. Morphology is forced pool riffle and plane-bed; LWD is a significant roughness element. The dominant substrate is gravel, with appreciable sand and cobble. This channel type is relatively sensitive to increased coarse sediment inputs, which are expected to result in bar growth and bank erosion. This channel type is also highly sensitive to LWD. Pools are frequently formed by LWD, and jams have the potential to induce formation of active floodplain features in typically entrenched channels. Loss of LWD would simplify channel morphology to plane-bed.

GCU 3. Low Gradient Pool-Riffle. This unit is found interspersed with GCU 2. It is unconfined

and has a relatively broad floodplain of riparian wetlands. Mobile gravel bars and sand patches are common; morphology is pool-riffle. Historic beaver activity and underlying glacio-lacustrine sediment strata may affect morphology. This GCU is highly sensitive to increases in coarse sediment delivery because of relatively low transport capacity and potential for bar growth and associated bank erosion. This channel type is also highly sensitive to LWD, which induces pool formation in a relatively mobile bed.

GCU 4. Moderate-gradient Avulsing. This unit occurs at the boundary between glaciated mountain terrain and the glacial sediments mantling the Swan Valley. It is a unit where stream gradient is declining relative to areas upstream, but is steep relative to areas downstream. Groundwater upwelling is thought to be common in this unit. Channel avulsions are relatively common, and LWD is a significant element of channel morphology. Morphology is step-pool and forced pool-riffle, with some plane bed reaches. Substrates are cobble and gravel with a significant proportion of boulders. Sensitivity to coarse sediment is similar to that of GCU 2. This GCU is particularly sensitive to LWD, which is thought to be critical in retaining gravel and creating pools. LWD also plays a major role in channel migration processes by inducing channel avulsions; side channels thus formed reduce overall stream power and promote storage of gravel.

GCU 5. Braided Floodplain. This unit occurs in a landscape setting similar to GCU 4, and was found only on the west side of the Swan Valley along the front of the Mission Range (dip slope subsection). Channel gradient is typically less than GCU 4, but is more variable. Segments of GCU 5 are sharply bounded both upstream and downstream by steeper stream reaches. This unit is typified by multi-thread channels with pool-riffle, forced pool-riffle, plane-bed and forced step-pool morphology. The dominant substrate is gravel and cobble, with significant proportions of sand and boulder. LWD is often a significant component of channel morphology. Sensitivities to coarse sediment, LWD and channel migration are similar to that of GCU 4.

GCU 6. Glacial Trough/Incised Mainstem. This unit occurs in alpine glacial valleys where it has entrenched glacial deposits generally classified as moraines. Channel slope is moderately steep, and channel substrates include gravel, cobble and boulder. Morphology is step-pool and cascade.

GCU 7. Ground Moraine Intermittents. This unit occurs on well-drained glacial deposits in upland positions on the floor of the Swan Valley and on the footslopes of mountain escarpments. Many of these "channels" represent relict drainage positions that do not presently carry significant surface flow; these areas often have some wetland characteristics. A minority of segments support significant seasonal flow (e.g., from a lake upstream) or relatively small perennial flows (e.g., spring-fed). Slope and morphology is variable. In the rare cases where flow is significant, sensitivity to increased inputs of coarse and fine sediment may be high owing to relatively low stream power. Fish use is not significant.

GCU 8. Scarp-slope Headwaters. This unit is defined by mountain escarpments (scarp slope

subsection) rising steeply along the eastern margin of the Swan Valley. Soils on these slopes are residual; glacial deposits are only locally significant. Channels are perennial or intermittent, steep, and have cascade morphology. Surface flow from these channels infiltrates unconsolidated deposits on mountain footslopes. No known fish use.

GCU 9. Cirque Headwaters. This unit is found in alpine glacial cirques interspersed with lakes and is typically perennial. Channel profile in cirque basins is stair-stepped, with a variety of channel slopes and morphology. Boulders and bedrock are prominent channel features in steeper reaches; gravel is common in low-gradient reaches flowing through meadows and forested parks. Fish use thought to be by non-migratory species only.

GCU 10. Headwaters with Avalanche. This channel type is typically intermittent and drains mountain ridges. Snow accumulation zones near the channel heads are source areas for snow avalanche. Channel slope declines near the floors of alpine valleys, creating avalanche deposition sites that modulate delivery of material to mainstem channels (typically GCU 6). Some of these channels intersect lenses of glacial deposits, creating potential for shallow landslides or debris flows. No known fish use.

GCU 11. Fans. This channel type is sparsely mapped, and includes avalanche deposition zones in alpine glacial valleys. Channel avulsion-related avalanche or mass wasting is episodic. A variety of slopes and morphologies are likely. Potential fish use if connected with fish-bearing streams.

GCU 12. Troughwall Cascades. This unit is comprised of steep channels that flow in cascades and waterfalls down the walls of alpine glacial valleys. They connect hanging glacial valleys with mainstem glacial valleys. No known fish use.

GCU 13. Upper Glacial Trough Alluvial. This rare unit occurs in low gradient segments of alpine glacial valleys, probably at confluences of significant tributary glaciers. Its characteristics and sensitivities are similar to those of GCU 2; it is used by fish.

12. COMPARE SUPER GUILDS AND GCU's

Guilds and super guilds were initially developed independently from GCU's, and although both approaches to classification relied on similar (and independent) survey data, the former focused on fish habitat over a broader area of about 400,000 ac., while the latter concentrated on fluvial and landscape geomorphology in two smaller tributary watersheds representing about a tenth of the larger study area. It was anticipated that these different approaches would yield relatively consistent results and thereby demonstrate in robust fashion the linkage between geomorphic characteristics and fish habitat parameters.

The seven preliminary super guilds (based on k-means cluster analysis; see Cluster To Super Guilds) were compared to GCU's and super-GCU's (generalized landscape-scale groupings of GCU's) to evaluate whether super guilds were consistent with a general level of geomorphic classification. This process revealed that a substantive inconsistency occurred in only one of the preliminary super guilds. In the preliminary constitution of super guild 3, two of the component guilds (SL2A-CO2-LTC7 and SL2B-CO2-LTC7) occurred in two significantly different GCU's (4 and 6), and were grouped with 7 other guilds that were consistent with one another. Consequently, the two inconsistent guilds (SL2's) were reassigned to a super guild of their own (super guild 8). Thus, the final grouping of guilds into super guilds based on the combination of watershed analysis and cluster analysis resulted in eight super guilds (Table 12). Figures 7 and 8 display the spatial correspondence of GCU's and super guilds within the Goat Creek and Piper Creek analysis areas, respectively.

Although the mutual independence of the two classification approaches was beneficial, it also created some inconsistency in survey sampling, and ultimately, interpretation of channel types. Field surveys for the geomorphic classification effort did not evenly or completely sample all the guilds and super guilds. Table 10 cross-references survey sites and GCU designations with guild and super guild designations. In addition, some sites were sampled that did not occur in a guild because the guild type was too uncommon to meet minimum abundance criteria for significant guilds. For example, there were no surveys in super guilds 1, 6, and 7. Field sites selected to develop GCU's included only 12 of the 26 guilds and 5 of the 8 super guilds.

Super guilds 2, 3, 4 and 5 partition survey sites into groups of GCU's with slopes either ≥ or < 5 %. The 5% threshold is significant because there were no GCU's with concentrated fish use with slopes > 5%, and because 5% is a major slope break in the guilding scheme. In addition, 5% slope is at about the mid-point of the slope range expected for step-pool morphology, the steepest morphologic class where suitable habitat for salmonids typically occurs. Among super guilds not sampled, 1 and 7 had slopes < 5% and #6 had slopes ≥ 5%.

Sample data for super guild 4 are in conflict with GCU sample data in that the mean slope for that super guild is 3.5 %, whereas GCU's had mean slope ≥ 5%. However, given the small GCU sample size and the relatively high variance of slope in super guild 4, it is likely that slopes in this super guild may frequently exceed 5%. Moreover, guilds in the "SL" class have modal slopes in the 5-13% range, so super guild 4 must be expected to contain some steeper stream segments.

GCU sample sites in super guild 8 also commonly had sites both ≥ and < 5% slope. This super guild is composed of guilds with RLT's SL2A and SL2B. In both of these RLT's, > 10% of stream segments had slopes < 5% (Jensen and Dean 1996). GCU survey sites in super guild 8 happened to be concentrated in lower-gradient reaches rich with higher quality fish habitat, whereas guild survey sites tended to be in steeper reaches with lower-quality habitat.

After describing GCU's, broader groups of GCU's (super GCU's) were developed based on landscape-scale position (i.e., associated landforms) and sensitivity to forest management for the purpose of preliminary extrapolation to other areas in the Swan Valley. Five super GCU's were conceived (Table 11). The first three super GCU's contained most of the sample sites and known fish habitat. For these super GCU's, mean channel slope and the range of channel morphology (predicted and observed) were well distinguished from one another. The Ground Moraine and Mountain Front super GCU's had channel morphology that would be expected (and was observed) to provide high quality habitat for salmonids.

The *Ground Moraine Super GCU* represented major tributary streams flowing on the flat and gently sloping glacial sediment and alluvium mantling the floor of the Swan Valley. Dominant substrates were gravel, cobble and sand. Channel morphology was pool-riffle and plane-bed. Forced pool-riffle was also common, created primarily by LWD and resistant stream banks.

The *Mountain Front Super GCU* occurred at the landscape transition from the floor of the Swan Valley to the glaciated mountains of the Swan and Mission Ranges. Stream gradients averaged 3%. Morphology was plane-bed and step-pool. LWD was a critical component of channel morphology that not only created pool and velocity shelter habitat typical of forced pool-riffle and forced step-pool morphology, but also preserved spawning gravel by reducing stream energy available for sediment transport and by forming steps and eddies where gravel is deposited. LWD also contributed to the formation of side channels by trapping coarse sediment and deflecting stream energy toward banks. Consequently, this super GCU commonly contained significant channel migration zones. The presence of side channels also reduced peak stream energy and increased the potential for gravel storage. Owing to its proximity to mouths of alpine glacial valleys, boulders were abundant in the stream and added roughness and a major component of step-pool morphology. Groundwater upwelling also occurred in these streams as flow emerging from alpine glacial canyons encountered fan-like alluvial deposits at the gradient transition from mountain to valley. These conditions created an aquatic environment ideal for bull trout spawning (Weaver and White 1985).

The *Alpine Glacial Trough Super GCU* was composed of the major perennial tributaries flowing on the floors and lower slopes of the alpine glacial canyons and cirques. Mean slope, observed primarily in GCU 6, was 7.5%. Morphology was step-pool and cascade. Channel substrates were predominantly cobble, boulder and bedrock. LWD was a secondary element of channel morphology that had relatively little effect. Fish use was limited, and in some cases prevented by migration barriers.

The *Avalanche and Fan Super GCU* represented primarily intermittent headwater channels dominated by snow avalanche processes. Avalanche run-out zones in valley bottoms near confluences with larger perennial streams in the Alpine Glacial Trough could potentially contain fish habitat.

The *Intermittent Super GCU* was also comprised primarily of intermittent streams, which rarely included streams observed to have both summer flow and fish habitat. The few perennial channels were very steep headwater channels with no surface connection to fish-bearing streams.

In the next chapter, we provide a discussion regarding similarities among super guilds and GCU's, including the general descriptions and identifying characteristics of GCU's. This discussion is not strictly limited to field survey data.

13. DESCRIBE SUPER GUILDS

The combination of cluster analysis and watershed analysis grouped the 26 guild types into eight clusters or super guilds (Table 12). Step-wise multiple discriminant analysis identified gradient, mean percent surface fines, mean percent canopy cover, density of cutthroat trout, mean wood jam volume, number of levels of dominant substrate, density of brook trout, mean wetted width, mean percent boulders, densities of fish larger than 12 inches, densities of bull trout, densities of rainbow trout, and mean depth of non-pool habitats as the most important variables in discriminating among the eight super guilds (Table 13). Gradient, mean percent surface fines, and mean percent canopy cover contributed most to the overall differences among super guilds. These three variables reduced Wilks' lambda by 78%. The discriminant functions, which incorporated the 13 significant variables, achieved a classification accuracy of 60.4%. Figures 9a through 9g compare means (with 95% confidence limits) of significant variables among super guilds, while Figure 10 displays the distribution of super guilds in the Swan River valley. We present descriptive statistics for each variable by super guild in Appendix A.

Super guild 1 had a mean channel gradient that corresponded to pool-riffle and plane-bed morphology. These guilds had a low average gradient (2.0%), high mean surface fines (61.5%) and low canopy closure (28.3%) (Figures 9a-b). These guilds typically had relatively low wood jam volumes and boulder cover (Figures 9b-d); hence, they had relatively low morphologic and habitat diversity. They occurred on the floodplain and terraces of the Swan River and closely resembled GCU 1 and 3. The riparian zones consisted mostly of shrubs, sedges, and grasses, indicative of poor drainage. These channels supported mostly brook trout (5.16 fish/100 m^2) and few cutthroat trout (0.17 fish/100 m^2), bull trout (0.12 fish/100 m^2), rainbow trout (0.02 fish/100 m^2), and whitefish (0.03 fish/100 m^2) (Figures 9e-g). Most fish were 3-6 inches, while fish larger than 12 inches were rare in these guilds.

Super guild 2 also had a mean channel gradient that was associated with pool-riffle and plane-bed morphology, and to a lesser extent, step-pool morphology. These guilds had an average gradient of 2.6%, mean surface fines of 14.7%, and mean canopy cover of 43.5% (Figures 9a-b). These consisted of relatively wide channels with moderate amounts of wood jam volume and boulder cover (Figures 9b-d). These channels had relatively high morphologic and habitat diversity. They most commonly were associated with GCU 2 and 3, although a few were in

GCU 4 and 5. The characteristics of these GCU's and their relative proportions in this super guild are consistent with the characteristics that discriminate the super guild (Table 10). These guilds supported mostly 3-6 inch fish with very few fish larger than 12 inches. Brook trout were most abundant (2.98 fish/100 m^2) with fewer bull trout (1.00 fish/100 m^2), cutthroat trout (1.17 fish/100 m^2), rainbow trout (0.35 fish/100 m^2), and whitefish (0.26 fish/100 m^2) (Figures 9c-g). Compared with other guild types, bull trout and rainbow trout had relatively high densities.

Super guild 3 had a mean channel gradient associated with cascade morphology. Here, mean gradient was high (15.3%) and mean surface fines relatively low (18.0%) (Figure 9a). Mean canopy closure was high (68.6%) (Figures 9b), as expected with small upland stream channels with low mean channel widths (Figure 9c). Mean wood jam volume was quite low (6.7/m^3), while mean boulder cover was relatively high (29.2%) (Figures 9b-d). The characteristics of this super guild were not uniformly consistent with the cascade and step-pool channels of GCU'S 6, 9, 10, and 11 with which it was associated (Table 10). Steeper channel segments classified in GCU 9 were most representative, although larger channels classified in GCU 7 in some cases corresponded with this super guild. This super guild supported mostly 3-6 inch fish and few fish larger than 12 inches. Cutthroat trout (0.90 fish/100 m^2) and brook trout (0.49 fish/100 m^2) were most abundant in these guilds (Figures 9e-g). Relatively few bull trout (0.03 fish/100 m^2) and no rainbow trout or whitefish used these guilds.

Super guild 4 had a mean channel gradient that was representative of plane-bed and step-pool channels. Average gradient in these guilds was 3.5%, while mean surface fines and canopy cover were 56.5% and 63.6%, respectively (Figures 9a-b). Compared with other super guilds, mean percent surface fines was high in these guilds. Both mean volume of wood jams and percent boulder cover were low (Figures 9b-d). These channels had intermediate morphologic and habitat diversity. These streams were also narrow (Figure 9c), which was consistent with high canopy cover. This super guild was associated with GCU'S 6 and 11. Their combined characteristics were somewhat consistent with this super guild, although each had substantive differences. For example, GCU 6 did not have high concentrations of fine sediment, and channel slopes and widths would be at the upper end of the range for this super guild. GCU 11 (fans) was of limited extent, but had appropriate characteristics. Survey sites in GCU 9 did not occur in this super guild (Table 10), however, several channel segments classified as GCU 9 coincided with this super guild. Lower-gradient channel segments in GCU 9 correlated reasonably well with this super guild. Most fish in this super guild were small (0-3 inches). Brook trout were more abundant in this super guild (9.91 fish/100 m^2) than in any other super guilds (Figure 9f). Bull trout (0.05 fish/100 m^2), cutthroat trout (0.68 fish/100 m^2), and rainbow trout (0.01 fish/100 m^2) were less abundant than brook trout (Figures 9e-g). We found no whitefish in this super guild.

Super guild 5 had a mean channel gradient that represented pool-riffle and plane-bed channels. These guilds were characterized by mean gradients of 2.0%, mean surface fines of 11.2%, and

mean canopy closure of 63.3% (Figures 9a-b). These guilds also had moderately high mean wood jam volumes and percent boulder cover (Figures 9b-d). Thus, these channels had relatively high morphologic diversity. This super guild was associated with GCU'S 2, 4, and 13, which had characteristics consistent with this super guild; however, it was best represented by GCU 4. As in super guild 4, most fish in these guilds were small (0-3 inches). However, compared with other guilds, greater numbers of fish larger than 12 inches occurred in this super guild. Brook trout were most abundant (4.35 fish/100 m^2) with fewer bull trout (1.05 fish/100 m^2), cutthroat trout (1.58 fish/100 m^2), rainbow trout (0.04 fish/100 m^2), and whitefish 2.48 fish/100 m^2) (Figures 9e-g). Compared with other guilds, bull trout had relatively high densities.

Super guild 6 had a mean channel gradient that was typical of cascade channel morphology. It had a relatively high mean gradient (11.0%), canopy closure (80.9%), and boulder cover (34.1%) (Figures 9a-d). On average, it had 9.6% surface fines and LWD jams of 5.7 m^3 (Figures 9a-b). Compared with other super guilds, it had the greatest mean diversity of dominant substrate types. This super guild was not widely distributed, and there were no survey sites for geomorphic classification. It is best represented by steeper reaches in GCU 6 and 9. Fish generally ranged between 3 and 6 inches. We found no fish larger than 12 inches in this guild. Cutthroat trout were most abundant (7.40 fish/100 m^2), while both bull trout and brook trout numbered 0.03 fish/100 m^2 (Figures 9e-g). Cutthroat trout were more abundant in this than in any other super guild. We found no rainbow trout or whitefish in this guild.

Super guild 7 had a mean channel gradient that was representative of pool-riffle and plane-bed channels. This super guild had low mean gradient (1.4%), boulder cover (0.2%), and canopy coverage (10.7%), but the highest mean wood jam volume (69.3/m^3) (Figures 9a-d). The high mean volume of LWD jams is thought to reflect the tendency for LWD to be easily transported in larger channels with accumulation in relatively few, large jams. This likely exhibits a strong influence on morphologic diversity in a channel type with otherwise limited diversity. Mean surface fines were also relatively high (28.1%) (Figure 9a). Channels in this guild were relatively wider than those in other guilds (Figure 9c). This channel type was not sampled in geomorphic surveys. Its distribution was limited to the floodplain and terraces of the Swan River and therefore closely resembled GCU 1. Fish in this guild were generally between 3-6 inches; however, fish larger than 12 inches were relatively abundant compared with other guilds. Whitefish were most abundant in this guild (3.16 fish/100 m^2) with fewer brook trout (1.64 fish/100 m^2), rainbow trout (0.29 fish/100 m^2), and bull trout (0.03 fish/100 m^2) (Figures 9e-g). Compared with other guilds, rainbow trout had a relatively high density. We found no cutthroat trout in this guild.

Super guild 8 had a mean channel gradient that was representative of step-pool and cascade channels. These guilds had a moderately high mean gradient (8.3%), boulder cover (41.7%), and canopy cover (70.9%), but relatively low mean surface fines (12.4%) (Figures 9a-d). LWD jam volume and channel widths were intermediate. These characteristics suggest relatively high

morphologic diversity, particularly where forced step-pool morphology was abundant (e.g., in lower-gradient segments with abundant LWD). Super guild 8 was frequently associated with GCUs 4 and 6 (Table 10). Typically, GCU 6 is a mainstem tributary channel in a confined alpine glacial valley that flows directly into GCU 4 where the channel enters the broad, unconfined Swan valley. This relatively short transition zone (GCU 4) was readily defined using watershed analysis techniques. The broader landscape analysis used to generate guilds did not discriminate these transition zones specifically, but they generally correspond to boundaries between super guild 8 and either 2 or 5. As in most guilds, fish typically ranged from 3-6 inches, with very few fish larger than 12 inches. Bull trout (1.03 fish/100 m^2) and cutthroat trout (1.03 fish/100 m^2) were the most abundant salmonids in these guilds (Figures 9e-g). A few rainbow trout (0.01 fish/100 m^2) and brook trout (0.47 fish/100 m^2) occurred in these guilds, but no whitefish.

13.1 Difference Between Disturbed and Undisturbed Sites Within Super Guilds

Within each super guild, we assessed whether habitat and fish variables differed between sites with (disturbed) and without (undisturbed) land-use activities. As we described in section 5.2, a site was rated as disturbed if there was observable and measurable evidence that the total riparian stand structure, within 100 feet of both sides of the stream channel, had been altered more than 25% by fire, flood, timber harvest, landslide, grazing, and/or windthrow. However, we did not evaluate the degree of disturbance, either natural or man-caused, that had occurred upstream of each sample site. Hence, potential impacts from upstream disturbances (e.g. fine sediment transported from a disturbed site upstream of the sample site) were not considered and may tend to confound results, but only for those parameters that reflect inputs that could propagate from areas upstream (i.e. fine sediment, stream discharge and possibly coarse sediment). We used t-tests (SYSTAT 7.0) to assess differences in variables between disturbed and undisturbed sites within each super guild. We used separate-variance t-tests for samples with unequal variances and one-sample t-tests for comparing one sample to the mean of several samples. Although we ran 360 t-tests, we elected not to reduce the probability of a Type I error below 5%. Thus, there was a 100% chance that we rejected a true hypothesis of no difference. However, a larger Type I error offers greater statistical power (Hays 1988). Furthermore, in analysis of disturbed versus undisturbed sites, we are more comfortable rejecting a true hypothesis of no difference than accepting a hypothesis of no difference when there truly was a difference.

Of the 360 tests, only 15 (4%) were significant (Table 14; see Appendix B for more detailed results). We found no differences in fish and habitat variables between disturbed and undisturbed sites in super guilds 1, 4, and 7. Only one variable in each of super guilds 3, 6, and 8 differed significantly. Three of the 45 variables in super guild 5 differed significantly, while nine variables differed between disturbed and undisturbed sites in super guild 2. In the latter super guild, differences tended to favor the disturbed sites. For example, water depths, total number of functional wood, and numbers of bull trout were significantly greater in the disturbed sites than in the undisturbed sites (Appendix B). These findings suggest that, at least within the study area over the recent past (10-20 years), geomorphic setting is significantly more deterministic of the

array and quality of fish habitat conditions than natural or anthropomorphically-derived disturbance regimes

14. CORRELATIVE RELATIONSHIPS

Correlation among variables within super guilds were investigated to ensure that judgments regarding vulnerability of habitat to land management practices based on watershed analysis techniques (described in the following chapter), were not contradicted by stream habitat and biological data resulting from the development of super guilds. This step in the analysis builds confidence in extrapolation of vulnerability assessments to areas not assessed by watershed analysis. This element of the analysis is discussed in greater detail in subsequent chapters.

We used Pearson correlation matrices (NCSS 97) to test for associations among variables within each super guild. For convenience, we referred to physical habitat parameters as independent variables and fish population parameters as dependent variables. Because we used both fish and habitat variables to group similar guilds into super guilds, we did not expect to find many important relationships between variables within super guilds. That is, by using cluster analysis and watershed analysis, we minimized within cluster variance and maximized between cluster variance. Therefore, variables such as gradient, canopy cover, surface fines, and boulder cover would vary little within super guilds but greatly among super guilds. As a result, variables strongly correlated across super guilds may be less strongly correlated within super guilds. For example, bull trout numbers correlated positively with percent boulder cover across super guilds, but not within super guilds. We accepted significance at $P \leq 0.05$ to define significant correlations.

As expected, we found few meaningful relationships between variables within the various super guild types (Tables 15-22). Additionally, we found few consistent correlations among variables within super guilds. Within super guild 1, for example, water temperature and channel widths per wood jam correlated positively with numbers of all fish, while boulder cover and gradient correlated with cutthroat trout numbers (Table 15). In super guild 2, mean percent bank undercut correlated with all fish, while mean wetted width correlated with all fish in super guild 3 (Tables 16 and 17). Total pool area correlated with all fish in super guild 5 (Table 19). Because of small sample sizes (n=5) in super guilds 6 and 7, nearly all habitat variables correlated significantly with fish numbers (Table 20 and 21). However, examination of scatterplots indicated that there were virtually no meaningful relationships. Within super guild 8, mean volume of functional wood correlated positively with all fish numbers (Table 22).

15. VULNERABILITY MATRIX

One of the primary objectives of the fish habitat assessment in watershed analysis (WFPB 1995) is to document the quantity and quality of habitat for important life history phases, namely spawning and rearing (summer and winter). For the purposes of consistency, this information is

grouped according to the segregation of GCU's as developed by the channel analyst. Using the GCU's as a template for evaluation, the fish habitat analyst then uses the habitat and species distribution information to designate GCU's that are of greater relative importance for the life history phases of the species. For example, one GCU may be designated as exhibiting primary importance for cutthroat trout spawning while two other GCU's may be designated as critical for bull trout spawning.

Once the relative importance of each GCU is designated for each species and life history phase, the potential effects of modifications of input possesses (e.g., sediment, LWD, etc.) upon limiting habitat factors is evaluated. This cause/effect evaluation is then used, in consultation with the other analysts, to modify the channel sensitivity ratings (Table 9) to reflect the vulnerability of fish habitat components, resulting in a habitat vulnerability matrix (Table 23). For example, channels in GCU 3 were rated as being moderately sensitive, in terms of physical channel processes, to increases in fine sediment delivery (Table 9). The fish habitat analysis found that GCU 3 was important spawning habitat for bull trout and that even moderate increases of delivered fine sediment would likely result in decreased embryo survival. Hence, the channel sensitivity rating of moderate was upgraded to a fish habitat vulnerability rating of high for GCU 3.

This phase of the analysis resulted in several "upgrades" of sensitivity calls to vulnerability calls. Upgraded vulnerability calls for coarse sediment inputs (GCU 4) generally reflected the potential to impact important rearing habitat through reductions in pool volume. Upgraded vulnerability calls for fine sediment (GCU's 2, 3, 4, and 5) were indicative of probable impacts to spawning habitat. Upgraded ratings for vulnerability to peak flows (GCU 6) were primarily the result of potential impacts resulting from redd scour for spring spawners. LWD upgraded vulnerabilities (GCU's 6 and 9) reflect the relative importance of wood in providing important spawning and rearing habitat. Upgrades to riparian vegetation vulnerability (GCU's 3, 4, and 9) indicated the importance of streamside shrubs and grasses in providing bank stability and rearing habitat (undercut banks).

Degrees of vulnerability were rated as low, moderate, or high. A vulnerability rating of high indicated that significant variations of the given input process had a high probability of degrading fish habitat features critical to fish reproduction and survival. Conversely, a low vulnerability rating indicated that either significant shifts in habitat quality were not likely to occur, or if they did occur, fish populations were unlikely to be impacted.

During watershed analysis, we found that GCU's 3, 4, 5, and 6 generally exhibited the highest use by bull trout for spawning and rearing. Cutthroat trout exhibited the strongest association with GCU 6, but moderate numbers also used GCU's 2, 4, and 9. This relative distribution of native species comports well with our findings of fish distribution by super guild (see Describe Super Guilds).

16. COMPARE VULNERABILITIES TO RELATIONSHIPS

In this chapter, we assessed the consistencies of habitat vulnerabilities for GCUs (Table 23) with significant correlative relationships for corresponding super guilds (Tables 15 through 22). The intent of this analysis was to determine if the relationships between dependent (fish) to independent (habitat) variables within specific super guilds agreed, or disagreed, with the vulnerabilities assigned to coinciding GCU'S. For example, if the fish habitat vulnerability to fine sediment was rated as high within a given GCU, we would expect to find a significant inverse relationship between fish density and percent surface fines (or dominant substrate class) within the corresponding super guild. As discussed in the chapter entitled Correlative Relationships, we did not expect absolute adherence to this postulate. That is, because our intent was to reduce the within super guild (cluster) variance, and thus maximize variance between super guilds, we would not expect to find strong relationships between fish and habitat metrics within super guilds. Hence, the focus of this assessment was to document and evaluate any consistent disagreement between super guild-derived correlations and GCU-derived vulnerabilities.

First, it was necessary to cross-reference GCUs and super guilds for the comparison of vulnerabilities and correlations, respectively. The analyses conducted in the previous chapters were used to develop a cross-tabulation of super guilds and GCUs (Table 24). This cross-tabulation was then used as a template for the assessment of GCU fish habitat vulnerabilities (Table 23) in order to create a hypothesized set of habitat vulnerabilities for Super Guilds (Table 25). If a super guild was found to contain more than one GCU, the respective vulnerabilities of each GCU for a specific input process were combined to designate the hypothesized super guild vulnerability for the same input process. The vulnerability was designated via one of the following four scenarios: 1) all corresponding GCUs exhibited the same vulnerability, resulting in the super guild vulnerability being equivalent; 2) there was an even split of vulnerabilities for corresponding GCU's, resulting in an even split vulnerability for the super guild; 3) in cases where there was a majority of adjacent GCU vulnerability rankings, we selected the dominant, or modal, vulnerability for inclusion to the super guild; 4) in cases where the GCU vulnerability rankings were equally low and high, or where there were inclusions of low, moderate, and high, we directly included all cases (instances of this scenario are discussed in greater detail in the next chapter).

Hypothesized vulnerability rankings (Table 25) for each super guild were compared with the respective significant independent-dependent variable correlates (Tables 15 through 22). Our approach to potential modification of hypothesized vulnerabilities was conservative so as to favor aquatic resources. As indicated above, we searched primarily for consistent disagreement between correlates and hypothesized vulnerability rankings. Only in this situation did we consider modification of a vulnerability ranking. This precluded the modification of super guild vulnerability rankings in situations where disagreements were either inconsistent or not

statistically significant (α =0.05). Once all consistent and significant disagreements were identified, the respective hypothesized vulnerability rankings were modified to result in a finalized set of vulnerability rankings for all super guilds (Table 26, next chapter). Below, we discuss observed anomalies and all necessary revisions.

Super Guild 1

Evaluation of significant correlative relationships between independent and dependent variables for super guild 1 (Table 15) demonstrated consistent positive relationships between fish densities and channel widths per jam. That is, fish density increased as the frequency of LWD jams decreased, as opposed to a hypothesized moderate to high vulnerability of fish habitat to LWD (Table 25). Assessment of descriptive statistics for super guild 1 (Appendix A) showed that despite a relatively low LWD density (functional pieces per width) in general, channel segments exhibited modest percent pool area. Since these channels generally exhibited pool-riffle morphology, they would form pool habitats as a matter of substrate scour and deposition, even in the total absence of in-channel wood (Montgomery and Buffington 1997). Since natural LWD recruitment to these channels was relatively low, we elected to downgrade the tentative moderate to high LWD vulnerability to a moderate vulnerability.

Super Guild 2

Our assessment of the relationships for this super guild (Table 16) yielded no consistent deviation between hypothesized vulnerability and significant correlates between fish and independent variables. However, we noted inverse correlations between 9-12 and >12 inch fish and percent pool area and a positive correlation between >12 fish and channel widths per jam. These anomalous relationships likely resulted from the fact that the measured density of large bodied fish in this super guild was very low, and overall LWD density and pool area was high. Hence we found no compelling justification to change hypothetical vulnerability to LWD.

Super Guilds 3, 4, 5, 6, 7, 8

Comparison of correlations to the hypothesized vulnerability class for these super guilds provided no compelling reason for modification. No consistent significant disagreement between correlates and tentative vulnerability calls was noted. Hence, hypothesized habitat vulnerabilities for these super guilds were accepted as final.

17. ID SURROGATES

In this chapter we provide the final vulnerability table for super guilds. This table, in combination with Figure 10 (super guild distribution), can be used by land managers to identify the probable vulnerability of fish habitat in any guilded channel segment in the Swan River watershed. Knowledge of the spatial distribution of these vulnerabilities allows for the confident application of specific prescriptions developed through watershed analysis when comparable information regarding delivered hazards is available (see Classify Hazards by Landtype). If such

information is not available, site specific measures can be developed to prevent or avoid impacts relative to local channel vulnerability. Table 26 is the final vulnerability table. In general, vulnerabilities for GCU's developed through watershed analysis could be consistently applied to super guilds. Cases where vulnerability straddled two adjacent rankings (i.e., L/M or M/H) were considered to be sufficiently consistent. However, certain cells in the matrix formed by watershed input variables and Super guilds (indicated by an asterisk in Table 26) contain vulnerabilities that varied significantly. The causes and interpretation of each of these cases are discussed below.

In Table 26, the interpretation of vulnerability to channel migration processes is somewhat different than for other watershed input variables. It is considered an overall potential of channel migration. Where channel migration potential is relatively high, it is accentuated by increased inputs of LWD and/or coarse sediment, which reduce the flow capacity of the existing channel, and by disturbance of riparian vegetation, which reduces the resistance of stream banks to erosion. In general, stream reaches with channel migration zones had more favorable habitat conditions. The intent of identified moderate or high vulnerability to channel migration is not to eliminate channel migration, rather, it is to alert managers that the stream ecosystem is more intimately connected with the floodplain and riparian vegetation in these reaches.

Super Guild 1

Super guild 1 has vulnerabilities for fine sediment and riparian vegetation that alternate between low and high. This reflects the fact that this super guild contains GCU's 1 and 3, which have divergent vulnerabilities to these watershed input variables (Table 9). The low vulnerabilities are associated with GCU 1, described as the Swan Floodplain and referring to reaches of major tributaries crossing the floodplain of the Swan River. In this geomorphic setting, fine sediment is expected to be relatively abundant owing to generally low channel gradient and associated deposition potential and to the relative abundance of fine sediment in the banks. Accumulation of fine sediment is limited, however, by the relatively high stream power found in this channel type compared to stream power in GCU 3 (Table 8). Moreover, the hypothesized biological significance of fine sediment—deleterious effects on spawning habitat—is generally of little practical concern owing to the limited use of this GCU for spawning. In contrast, GCU 3 (Low Gradient Pool-Riffle) has similar morphology to that in GCU 1, but it occurs in lower order channels that are in proximity to higher-quality spawning and rearing habitat (e.g., GCU 3 also occurs in super guild 2). GCU 3 also has lower stream power and is therefore more vulnerable to fine sediment accumulation.

The vulnerability of super guild 1 to changes in riparian vegetation is low in reaches that are consistent with GCU 1 and high in those with characteristics of GCU 3. In GCU 1, stream size and bank height is greater, reducing the potential influence of roots on bank integrity. In GCU 3, stream size is smaller and habitat quality is greater, indicating potentially significant habitat effects if riparian vegetation is subjected to intensive management (e.g., excessive grazing).

Reaches in super guild 1 with high vulnerability to fine sediment and disturbance of riparian vegetation can be distinguished in the field from those with low vulnerability according to the following criteria. Those tributary channels immediately adjacent to the Swan River flowing on the floodplain or terrace of the Swan River, with gradient of about 1% or less, are presumed to have low vulnerability to fine sediment and riparian vegetation disturbance. All other reaches in super guild 1 are presumed to have high vulnerability to fine sediment and disturbance of riparian vegetation. These reaches are expected to have gravel beds with substantial sand deposits and to flow through areas with a significant component of meadow and shrub vegetation.

Super Guild 3

The vulnerability of super guild 3 to coarse and fine sediment can be either low, moderate or high. This arises from variations between and within GCU 7 (Ground Moraine Intermittents) and GCU 9 (Cirque Headwaters). The vast majority of stream reaches in GCU 7 are insignificant ephemeral channels, which have low sensitivity to sediment. In rare cases, channels in GCU 7 carry significant intermittent or perennial flow, and potentially support fish habitat. The morphology of these uncommon, habitat-containing channels classified in GCU 7 varied from pool-riffle to step-pool and cascade. In general, pool-riffle or plane-bed channel types containing fish habitat have high vulnerability to coarse and fine sediment while the others have low vulnerability.

Similarly, GCU 9 contained some reaches with moderate vulnerability to coarse and fine sediment. This channel type lies in headwater valleys scoured by alpine glaciers. Consequently, there is a stair-step longitudinal valley profile. There are some lower gradient areas in alluvial material, particularly near lakes, where channel morphology features include significant gravel bars, pools, and stream banks that could be eroded. These channel types have moderate vulnerability to sediment.

With respect to vulnerability of super guild 3 to disturbance of riparian vegetation, GCU 9 contained reaches with either low or high vulnerability. Reaches that have potential for bank erosion, which are expected to be the same reaches with sediment vulnerability, have high vulnerability to disturbance of riparian vegetation. Reinforcement of bank strength by roots of grasses and shrubs, and to a lesser extent trees, are thought to be critical to bank stability in these areas.

In the case of channels in GCU 7, vulnerability of riparian vegetation is considered either high or moderate. It is high in those reaches with sediment vulnerability because these are the same areas with banks that can be eroded, and root reinforcement is critical for bank stability. In contrast, all other channels (including swales with intermittent or ephemeral flow) have moderate vulnerability to disturbance of vegetation. In this case, the presence of vegetation contributes to the absence of a channel because of the resistance to erosion offered by stems and roots of

vegetation, and evapotranspiration that reduces the potential volume of surface water. If these plant communities were severely disturbed, it is possible that gullies would form and eroded sediment could be delivered to vulnerable streams. This potential management effect was not observed in the watershed analysis subbasins. Forest managers may have experience with the effects of operating in these areas and may be justified in modifying this vulnerability call.

Recognition in the field of sites with high or moderate sediment and riparian vegetation vulnerability (as distinguished from low vulnerability) is based primarily on distinguishing areas of relatively low channel gradient in generally high gradient segments. Reaches with local slope of greater than 6% have low vulnerability. Reaches with slopes less than or equal to 6% but greater than 2%, and that have banks composed of greater than 50% gravel (or finer) sediment, and show some evidence of bank erosion have moderate sensitivity to sediment and riparian vegetation. Reaches with slope less than 2% have high vulnerability to sediment and riparian vegetation disturbance; if the banks do not show strong evidence of erosion and are armored by cobbles, boulders and bedrock, riparian vegetation vulnerability is low.

Super Guild 4

The vulnerability of super guild 4 to disturbance of riparian vegetation varies from low to high because three GCU's (6, 9 and 11) represent this super guild. GCU 6 has low vulnerability because channel banks are armored primarily by boulder and cobbles, and root reinforcement is not considered to be significant to bank stability. As described above in relation to super guild 3, GCU 9 has some areas with high vulnerability to disturbance of riparian vegetation.

GCU 11 (Fans) has a wide variety of potential channel morphology in the geomorphic classification. This unit was defined primarily in connection with steeper, confined headwater streams with potential for avalanche and mass wasting. The Fan GCU is comprised of reaches of declining gradient and confinement on valley footslopes where sediment and LWD transported from headwaters are deposited. Because these channels have the potential to shift position in response to sudden inputs of water, sediment or LWD, and because the banks are composed of erodible sediment, it was generally concluded that riparian vegetation, primarily trees, but possibly shrubs as well, would reduce the potential for bank erosion. This channel type has moderate vulnerability to disturbance of riparian vegetation.

Vulnerability to disturbance of riparian vegetation is recognized in the field according to channel slope and bank characteristics. If channel slope is greater than 6%, vulnerability is low. Reaches with slopes less than or equal to 6% but greater than 2%, and that have banks composed of greater than 50% gravel (or finer) sediment and that show some evidence of bank erosion, have moderate sensitivity to riparian vegetation. Reaches with slope less than 2% have high vulnerability to riparian vegetation disturbance; if the banks do not show strong evidence of erosion and are armored by cobbles, boulders and bedrock, riparian vegetation vulnerability is low.

Super Guild 6

The vulnerability of super guild 6 to disturbance of riparian vegetation is either low or high, depending on local conditions. This Super guild is comprised of channels classified in GCU 6 and GCU 9. As described above, portions of GCU 9 channels (typically those with lower gradient) have high vulnerability. Other segments in GCU 9, and those in GCU 6, have low vulnerability. Determination of vulnerability can be determined by the field criteria as described for super guild 4.

Super Guild 8

The vulnerability of super guild 8 to coarse sediment, riparian vegetation, and potential for channel migration may be either low or high. Streams in this super guild were found in both GCU 4 (Moderate Gradient Avulsing) and GCU 6 (Glacial Trough/Incised Mainstem). The majority of stream segments in this super guild are in the relatively steep and confined channels of GCU 6. Here, vulnerabilities are low because boulder- and cobble-dominated beds and banks reduce the potential for bank erosion and channel migration. In addition, stream power is relatively high because channel slope is relatively high and channels are incised/confined, reducing the potential for widespread formation of large gravel bars and sediment deposition in pools.

In contrast, channels in GCU 4 have high vulnerability to coarse sediment, riparian vegetation, and a high probability of channel migration. The morphology of this GCU is diverse, and includes plane-bed, forced pool-riffle, step-pool and forced step-pool. LWD is a significant component of channel morphology, forming steps and obstructions that scour pools and sort and store gravel. Inputs of substantial quantities of additional coarse sediment would be expected to cause deposition in pools or growth of bars, which would be likely to induce bank erosion. Banks are composed of cobble and gravel, and the influence of roots (primarily of trees) on bank stability is significant. These channel have slopes of 4 to over 5% and are quite powerful; they are capable of eroding banks and forming new side channels or reoccupying abandoned channels when new channel obstructions form. This process of channel migration by channel avulsion is thought to be a key geomorphic and ecological characteristic of this channel type, which among other things, reduces stream power available for transporting gravel and creates high flow refugia for fish. The high vulnerabilities reflect the interpretation that these channels are sensitive to changes in inputs that could accelerate natural processes. However, it is not possible or desirable that management efforts eliminate channel migration in this channel type.

Field recognition of reaches in super guild 8 with high vulnerability to coarse sediment, riparian vegetation disturbance and channel migration is based primarily on channel slope. Reaches with mean slope of 6% or less (as measured in the field) over a distance equivalent to at least 300 ft (roughly 10 to 20 channel widths) are considered to have high vulnerability. All others are considered to have low vulnerability.

18. IDENTIFY HAZARDS

Once the watershed analysis assessment team had worked through their individual modules, information from all modules was synthesized to develop a comprehensive picture of the watershed processes. This information was then used to link resource effects to existing or potential hazards and to consider the existing or potential cumulative effects of multiple land management practices. These "cause-and-effect" linkages were summarized in causal mechanism reports to help the prescriptions team develop appropriate management responses in spatially focused areas.

Synthesis of the information resulted in the development of nine causal mechanism reports (CMRs) for the Goat Creek and Piper Creek analysis areas. Four CMRs were developed for the existing and/or potential delivery of coarse and fine sediment through mass wasting processes. Three CMRs were developed for the existing and/or potential impacts resulting from harvest of riparian timber. Two CMRs were developed for the existing and/or potential delivery of fine sediment through road erosion. Each CMR developed for the Goat and Piper Creek Watershed Analysis is discussed below and summarized in Table 27. With regard to watershed hydrology, peak flows generated from rain-on-snow runoff events were calculated to be within 10% of background. As such, peak flows augmented by increased snowmelt during rainfall did not appear to be a significant factor in the Goat, Squeezer, or Piper Creek watersheds. For spring "clear-sky" snowmelt conditions, the snowmelt estimates indicated that the spring peak discharge was not impacted by snowmelt in areas of forest management, based on the simulated distribution of snowmelt calculated for a hypothetical clear spring day. As such, a hydrologic hazard rating of low was assigned for both watersheds.

CMR A1. This causal mechanism report was written for two landform units that have a high potential for mass wasting, which could deliver coarse and fine sediment to stream channels thereby impacting downstream spawning and summer and winter rearing habitat for fish. One landform unit was *Over-steepened Toe Slopes*, which occupied 53 acres in Squeezer Creek (a tributary to Goat Creek). The second landform unit was *Inner Gorges*, which occupied less than 615 acres in the analysis area. Inner gorges in the Swan were over-steepened canyon walls created when streams downcut into unconsolidated glacial sediments. In most cases in the watershed analysis area, inner gorges were created when high-energy streams (e.g., GCU's 1, 2, 4, 6, and 13) downcut into Ground Moraine or Glacial Outwash LTC's. Within the 615 acres of potential *Inner Gorge* identified, high hazards only existed within 100 feet of streams, where slope gradients exceed 80% (or 60% where evidence of groundwater seepage existed). Activities that may promote further instability in these landforms include intensive timber harvest, which would reduce rooting strength, road construction, or concentrating road/skid trail drainage onto failure-prone areas.

CMR A2. This causal mechanism report was developed for *Steep Rocklands*, which have a

moderate potential for mass wasting and could deliver coarse and fine sediment to streams. This landform unit occupied 10,237 acres in the headwaters of both Goat and Piper Creeks and typically corresponds to the Rockland Landtype Class (LTC) . Although this unit occupied almost 32% of the analysis area, the lack of merchantable timber on these steep, rocky slopes, makes forest management an unlikely triggering mechanism. Additionally, little potential exists in much of the mapped landform unit for delivery of sediment to fish-bearing streams.

CMR A3. This CMR was written to address potential hazards within *Steep Alpine Lands,* and for two *Deep-Seated Landslides. Steep Alpine Lands* are lands that have been subject to alpine glaciation, and typically have slopes between 40%-80%. This map unit occupied a total of 9700 acres, most of which was in high-elevation areas of the Goat Creek watershed. Steep Alpine Lands typically included the Glacial Trough, Residual, and Glacial Basin LTC's. Moderate hazards exist in this map unit where slope gradients are greater than 80% within 100 feet of stream channels, or greater than 60% if evidence of seepage or slope movement exists within 100 feet of stream channels. Two potential *Deep-Seated Landslides* occurred in the analysis area. One was located in the Mission Mountain Wilderness in the headwaters of Piper Creek. The other is located adjacent to Squeezer Creek. These deep-seated landslides typically occurred where streams have downcut into the Ground Moraine LTC. Potential triggering mechanisms that could decrease slope stability in these areas include road construction along toes of landslides, concentration of road drainage onto steep slopes or deep-seated landslides, timber harvest on steep slopes, and broadcast burning on steep slopes.

CMR A4. This CMR was written to address potential cut-slope mass wasting hazards associated with roads constructed in *Glacial Moraine Deposits with Seep Potential.* This landform unit often contains significant groundwater seepage and is associated with the contact between glacial deposits (primarily the Ground Moraine LTC) and residual hillslopes (primarily the Glacial Trough or Residual LTC). This map unit encompassed 264 acres within the analysis area. Moderate hazards exist only where slopes exceed 60% with evidence of groundwater seepage, and are within 100 feet of stream channels. Triggering mechanisms include road construction, concentration of road drainage onto these steep slopes, and cable or ground-based yarding skid trails that concentrate water onto steep slopes.

CMR B1. This causal mechanism report addresses the potential for ditch erosion resulting from interception of subsurface flow by road and skid trail cut slopes. Although this situation has not created a significant erosion problem in the watersheds analyzed, it has the potential to cause problems elsewhere. These areas have not been mapped, but occur on steeper slopes and in areas where glacial terraces meet residual hillslopes (e.g., Ground Moraine LTC's adjacent to Glacial Trough or Residual LTC's). Another indication of the potential for this situation is the presence of cedar or grand-fir habitat types.

CMR B2. This CMR was written to inform land managers where high-priority road sediment

delivery locations exist. Although the overall fine-sediment delivered hazard from roads was rated as "low," a number of opportunities exist to further reduce fine sediment delivery to streams.

CMR D1. This CMR addressed two channel segments where timber harvest prior to state regulations decreased the near-term potential for large woody debris recruitment to the stream, and canopy cover for temperature moderation. One segment was located in lower Piper Creek, the other in lower Squeezer Creek. A total of 1.5 miles of stream were affected by this CMR, or 1.6% of the total stream network in these watersheds.

CMR D2. This causal mechanism report was written for channel segments within GCU's that exhibited moderate-to-high sensitivities to LWD recruitment, riparian vegetation, or channel migration zones. With regard to LWD recruitment, 13% of the channel network was classified as highly vulnerable, while 84% was classified as moderately vulnerable to LWD recruitment. With regard to riparian vegetation, 35% of the channel network was classified as having a moderate-high vulnerability. In terms of channel migration potential, 4.5% of the channel network was considered highly vulnerable, while 22% is considered moderately vulnerable.

CMR D3. This CMR addressed an uncertainty about two channel segments that were not surveyed in an unnamed tributary to Goat Creek. Historic timber harvest along this reach of stream reduced near-term LWD recruitment below desirable levels and reduced streambank vegetation.

19. CLASSIFY HAZARDS BY LANDTYPE

Watershed analysis rigorously identifies locations where moderate or high hazards exist for delivery of coarse and fine sediment, peak flows, and large woody debris. It also evaluates how past, and potential future forest management could affect these input processes. With practice, watershed analysts can identify reoccurring patterns in a landscape and gain more experience recognizing potential hazards to fish and water resources. Consequently, do we have to conduct watershed analysis in every drainage to assess these hazards, or can we learn from one watershed and extrapolate hazards to similar watersheds? Or, are hazards so site-specific that all areas must be analyzed? This section discusses approaches for extrapolating erosion hazards to adjacent watersheds in the Swan River basin.

19.1 Mass Wasting

Mass wasting in Goat and Piper creeks is rare, as evidenced by the discovery of only five management-related landslides in a 51 square mile analysis area. This low frequency of mass wasting is similar to rates observed in other watersheds in western Montana and northeast Washington (McGreer et al. 1998) When landslides were associated with forest management, they rarely delivered sediment to streams. The two cases where mass wasting appeared to be a

high hazard with regard to forest land management were: 1) inner-gorge landforms, where high-power streams have down-cut into glacial or sedimentary deposits; and 2) deep-seated landslides in fine-textured soils that are adjacent to streams. As discussed earlier, *Inner Gorges* and *Deep Seated Landslides* are found in isolated locations where high-energy streams (e.g. GCU's 1, 2, 4, 6, and 13; super guilds 2, 5 and 8) have severely downcut into Ground Moraine or Glacial Outwash LTC's. Moderate hazards were identified for steep landforms that are potentially prone to shallow-rapid landslides.

For the Goat and Piper Creek watershed analysis, mass wasting hazards were described for nine distinct landforms. Landforms prone to shallow-rapid landslides were largely based on landtype and General Landtype Class (LTC) mapping summarized in Jensen and Dean (1996).

Though inner-gorge landforms were not identified in the ecological classification. The classification does map the extent of glacial deposits. A map of Ground Moraine and Glacial Outwash LTC's can be overlain on USGS 7.5 minute topographic maps to identify where steep slopes are adjacent to higher-energy streams. Following aerial photograph interpretation and ground-truthing, a map of inner gorge landforms would be relatively simple to prepare. This task is currently underway for Plum Creek ownership in the Swan Valley and is expected to be completed by March, 1999.

With regard to deep-seated landslides, these features can only be identified from analysis of maps and aerial photographs, or through field reconnaissance. Mapping of deep-seated landslides in the Swan River valley has been completed in the landtype mapping by Martinson and Basko (1983), Ford (1978), and Sirucek (unpublished data). Previous mapping of deep-seated landslides will be verified during inner-gorge mapping. Any features that were missed by earlier investigators will be added.

The final product of this effort will be a mass wasting hazard map for Plum Creek lands in the Swan Valley. This map will be placed as an information layer on Plum Creek's geographic information system.

19.2 Road Erosion

Road erosion was found to be a low hazard in both the Goat and Piper Creek watersheds. However, road erosion is a very site-specific process and appeared to be more difficult to extrapolate to other watersheds. In Goat and Piper creeks the low road erosion hazard largely resulted because there were very few stream crossings that actually routed to fish-bearing waters and there were few roads constructed parallel with streams. For example, in the Goat Creek watershed, over sixty road locations were initially mapped as stream crossings. Upon field examination, only 18 locations actually had the potential to route sediment to fish-bearing waters. In many cases, mapped streams either did not exist, or they went entirely sub-surface as they traversed the glacial moraine. The erosion hazard also appeared to be largely independent

of the inherent erosivity of the underlying soil. Based on these results, we should expect road erosion to be more of an issue in other Swan watersheds in the following instances: 1) where there is a higher frequency of stream crossings that route to fish-bearing waters; 2) where significant lengths of road are constructed parallel to streams; and 3) where roads are not up to current BMP standards for drainage around stream crossings. Metrics for each of these parameters could be developed to screen other watersheds in the Swan for potential road erosion hazards.

19.3 Hillslope Erosion

Hillslope erosion from timber harvesting was not found to be significant in the Goat and Piper Creek watersheds. This was attributed to the high compliance rate with BMP's (particularly waterbarring of skid trails), and maintenance of streamside management zones (SMZ's) around waterbodies (per Montana's SMZ law). If these practices are in effect in other watersheds, and similar soil types and landforms are present, we have no reason to believe that hillslope erosion and/or sediment delivery would be significant.

However, one product of the surface erosion module in watershed analysis is a soil erosion potential map that categorizes the inherent erosivity of soils by Landtype Class or Landtype. In watersheds where hillslope or road erosion was found to be more closely correlated with soil type, this erosion potential information could be used to identify hazard areas where erosion from new or existing roads or timber harvests would likely be of concern. For example, if in the course of conducting a watershed analysis, hillslope erosion associated with ground-based equipment operation was found to be closely associated with mica-schist soils in a Residual LTC, the ecological classification mapping would provide a reasonable basis for predicting where this same circumstance would be expected throughout the mapping area. As will be discussed below, it would be expected that any prescriptions developed to address this particular hazard in the watershed analysis area would also be directly applicable in areas outside the watershed analysis area that is in the same LTC.

19.4 Summary

By coupling knowledge gained through intensive watershed analysis with ecological classification of larger areas, we believe we have a powerful approach to make preliminary determinations of locations where moderate to high hazards exist with regard to upland processes. With regard to mass wasting, hazards are typically associated with specific landforms. In many cases, these landforms are directly mapped in the ecological classification. In other cases, such as with inner-gorges, ecological classification provides information that expedites hazard mapping (e.g. mapping of soft-textured soil formations that would be conducive to stream downcutting).

With regard to road and hillslope erosion, completion of watershed analysis not only determined that low hazards existed, but identified the actual circumstances that resulted in the low hazard.

This knowledge can be used to screen other watersheds, grouping them into those that likely don't have road erosion hazards and those that likely do. Any such determinations would have to be validated by additional assessments. This same approach could be used to address issues relating to watershed hydrology. Although peak flow changes due to timber harvesting were not found to be significant in Goat and Piper Creeks, the watershed analysis also revealed the reasons why it was not an issue. Other watersheds can be screened for these characteristics to provide an initial hypothesis of their status that can then be validated through further assessments.

20. PRESCRIPTIONS

As discussed in the preceding section, additional analysis at the river basin scale is required to spatially correlate upland hazards, in terms of both degree of hazard and probability of delivery to sensitive stream reaches, with designated landtype classes. Once analysis is complete, this will enable the assignment of specific delivered hazard and vulnerability ratings to the combinations of all classified landtypes and stream reaches. This cross-referencing approach is necessary for the development of site-specific land management prescriptions. In addition, prescriptions for the management of riparian forest stands relative to channel sensitivity are described in Technical Report 7. Since our intensive watershed analysis did not classify riparian forest stands according to criteria developed in Technical Report 7, it was not possible to develop a comprehensive matrix for hazard and vulnerability relationships relative to timber harvest within riparian forest stands. These dilemmas render the presentation of distinctive prescriptions moot at this stage of development of Plum Creek's strategy for land management that conserves aquatic resources. At this time, we provide the framework necessary for prescription development.

Prescriptions are developed as a management response to watershed analysis findings. Hence, they are solutions to the issues or problems identified during the assessment process. In areas of resource vulnerability, prescriptions are developed to either minimize, or prevent and avoid, the likelihood of adverse change and deliverability that could adversely affect aquatic resources. Generally, prescriptions are developed as a response to causal mechanism reports, but may be developed for the restoration of previously impacted areas or as a preemptive response to hazard and/or vulnerability calls developed with a low level of confidence. Table 28 displays the decision matrix for prescription development.

When the matrix calls for application of standard rules, it is assumed that existing regulatory mechanisms in place (e.g., standard BMP's, SMZ rules, etc.) are effective in protecting aquatic resources. When the matrix indicates that the management response should be to minimize potential adverse effects, the intent is to develop prescriptions that minimize the likelihood of those circumstances or activities that would initiate or maintain a hazard condition. Where the matrix indicates that the management response should be to prevent or avoid potential adverse

effects, this indicates that those circumstances or activities that have the potential for adverse effects should be avoided or prevented from occurring. Prescriptions will generally be resource- and site-specific, but may include broad responses (e.g., road maintenance activities). Prescriptions may also include a verification step, such as determining if specific condition exists at the site of a proposed activity (e.g., does the degree of slope exceed a certain percent).

21. EXTRAPOLATE PRESCRIPTIONS

Vulnerability calls for all classified channel segments have been developed (see ID Surrogates). Once the additional analytical measures described above are completed (see Classify Hazards By Landtype and Prescriptions), the prescription matrix will be used to develop mitigative measures that protect aquatic resources. That is, resource vulnerability for each input process can be spatially designated via super guilds. In addition, a hazard rating for each input process can be spatially designated via individual or combinations of landtype classes. Depending upon the given scenario, we foresee the development of three types of extrapolated prescriptions: explicit, implicit, and refined. These types vary as a function of the degree and accuracy of information available, as well as the input process.

21.1 Explicit Prescriptions (Derived directly from watershed analysis)

Explicit prescriptions denote those circumstances that provide the opportunity for direct extrapolation of a prescription developed via watershed analysis to locales within the study area that directly mimic the combination of super guild (vulnerability), landtype class (hazard), and triggering mechanism (proposed activity and delivered input) for which the prescription was developed during the watershed analysis phase. For example, as a result of watershed analysis we developed a causal mechanism report (A1) to address the likely impact of the delivery of coarse and fine sediment, in landtype classes 7 and 8, (high hazard) to fish spawning and rearing habitat in GCU's 1, 2, 4, 6, and 13 (high and moderate vulnerability) as a result of new road construction across inner gorges with slopes greater than 60% and within 100 feet of stream channels, resulting in probable landslides (proposed activity and delivered input). The high hazard and moderate to high vulnerability calls, applied to the prescription matrix (Table 28), resulted in a prescription to prevent or avoid the development of this situation. That is, road construction in these areas is precluded unless a site-specific geotechnical analysis indicates that roads will not trigger landslides. The explicit prescription extrapolation will result in the application of this same prescription to corresponding areas in the Swan River basin: proposed road construction across super guilds 2, 5, and 8 bisecting landtype classes 7 and 8 with inner gorges >60% slope within 100 feet of channels.

21.2 Implicit Prescriptions (Developed in addition to watershed analysis)

Implicit prescriptions indicate those situations that allow prescription development for a proposed activity, based on the probability of a delivered hazard to a super guild exhibiting

vulnerability to said hazard, even though a causal mechanism report and subsequent prescription were not developed during watershed analysis. This prescription option is deemed necessary since the intensive watershed analysis did not capture all possible combinations of super guilds and landtype classes expressed in the Swan River basin. Prescriptions can be developed from the assessment of super guild vulnerability and adjacency (presumed deliverability) to a landtype class exhibiting a moderate to high hazard rating for an input process. Implicit prescriptions may also be developed through an adaptive management approach where a delivered hazard is observed to result from an activity in a specific landtype, and future similar activities in the same landtype can be adjusted where the hazard would be routed to a vulnerable super guild.

21.3 Refined Prescriptions (Developed with watershed analysis and other tools)
Refined prescriptions are applicable in those situations where an existing prescription already exists, but information provided by the ecoclassification can be used to enhance aquatic resource protection. Application of this prescription option will occur most often relative to timber harvest in riparian areas. Riparian management situations and a framework for prescription development are described in Light et al (1998). The report provides guidelines for the selection of riparian management prescriptions to achieve wood loading that matches the general sensitivities of stream channels. These sensitivities are based predominantly on slope class. The results of ecoclassification and guilding provide much more specific information relative to channel segments, namely 1) vulnerability to wood loading, and 2) desirable targets, by super guild, for both wood density and functional wood volume (Appendix A). Using the riparian stand/LWD recruitment model developed in Technical Report #7, we will be able to query the model to determine if existing stand condition and prescribed management scenario will properly address the revised vulnerability and targets (based on super guild metrics) and/or determine if additional protection measures are warranted.

22. EFFECTIVENESS MONITORING

As with any scientific investigation, findings and applications never anticipate all potential significant circumstances. There is an inherent uncertainty associated with the application of any model. The results of our successive analyses were often statistically strong, but the potential to compound error exists within the progressive, incremental framework of our approach. We are confident in the predictive capabililty of this process, but are compelled to provide options for the application of adaptive management approaches for the evaluation and subsequent modification of our model. We expect that the implementation of any or all of these options will increase the precision of this management strategy as time progresses.

The most obvious approach to test the effectiveness of extrapolated prescriptions would simply involve the application of prescriptions across the study area with subsequent monitoring of a variety of reference reaches, stratified by super guild, to determine if desired results are achieved. Desired results under this scenario may be defined as either: 1) maintenance of existing

conditions, or 2) a "net improvement" of conditions in channel segments known or perceived to be degraded. We recommend that the suite of parameters to be monitored under this baseline-reference approach would be physical variables, not biological. We advocate the use of physical variables based on two principals. First, the detection of adverse change in physical habitat variables would be more timely and efficient than through the use of biological indicators. Populations of organisms generally exhibit a lag-time in response to perturbation and the inherent population variance and mobility of biological organisms can confound monitoring protocols to the extent that results may be inconclusive. Secondly, biological populations fluctuate in response to stressors other than habitat condition. Hence, factors affecting recruitment such as fishing pressure, stocking programs, disease, and density-dependent responses can confound monitoring results to the extent that fluctuations resulting from habitat change are masked.

Another approach to test the accuracy of our model would be to beta-test the predictive capability of the super guilds. Appendix A provides descriptive statistics of the variables analyzed, grouped by super guild. Beta-testing could be implemented by applying the sampling protocol to unsampled super guild segments in order to determine if a significant difference exists between measured and predicted variables (as per Appendix A). Data collection and analysis for this beta-test is currently being conducted (summer and fall of 1998) with results expected by late 1998. Additionally, the complete extrapolation of watershed analysis awaits the demonstration that hillslope hazards can also be linked between the on-the-ground analysis and super guilds across the river basin via GIS. See discussion under sections 19.1, 19.2, and 19.3 for Plum Creek's commitments to spatially identify hillslope hazards across the Swan River basin.

An alternative beta-test approach for our model would be to assess the extrapolated hazard and vulnerability calls. Another watershed analysis could be conducted in an untested subbasin to determine the level of accuracy of our predictions. This mechanism could be used to assess both absolute accuracy and relative accuracy. That is, watershed analysis beta-testing may indicate 100 % prediction accuracy for one guild (or landtype), but find 70 % accuracy for another.

The final monitoring approach we suggest considers unguilded segments that have yet to be surveyed. The 27 significant guild types that we assessed comprised 74% of all tributary guilds classified. Hence, vulnerability ratings have not been developed for 26% of the perennial tributary watercourses in the Swan River basin. Albeit, most of these unassessed channel segments are small, steep headwater channels and not likely to support fish (see Figure 6), some portions may exhibit local biological significance. We propose an interim approach to designate vulnerabilities for these untested segments. Channel slope and width are two of the most important factors that can be used to determine channel sensitivity (e.g., Whiting and Bradley 1993). Since RLT classification and stream order classification have been developed for all of the perennial channels in the Swan River basin (Figures 3 and 4), it is relatively simple (with GIS analysis) to identify the combination of RLT and stream combined order class for any given

channel segment that has not been previously assessed and guilded. Once this combination is identified, we propose that the channel segment be associated with the super guild representing most similar geomorphic guilds, in terms of RLT and combined order class. For example, if the assessment of an heretofore-untyped channel segment results in a classification of SL2B-CO2, we suggest that it is likely to express resource vulnerabilities similar to super guild 8 (see Table 12). In the event of two super guilds equally representing one RLT/CO designation (i.e. SL2A-CO1), we recommend that the segment be grouped with the super guild exhibiting the most similar position on the landscape (see discussion of super-GCU's in Compare Super Guilds and GCU's). For those RLT/CO designations without correspondence to any significant geomorphic guilds (i.e., VS riparian landtypes), we recommend that they be grouped solely on the basis of landscape position. Hence, VS landtypes would be grouped with super guild 3. Once surrogate super guild "nesting" of unassessed stream segments has been completed, field evaluation could determine the success of this approach.

We expect that any, or all, of the above monitoring strategies are likely to result in improvement of our proposed model, with the ultimate benefit being realized by aquatic resources. The "feedback-loop" of any of these strategies is strong and direct, and would contribute to the commitment of adaptive management as advocated by both Lee (1993) and Walters (1996).

23. DISCUSSION

The strategy presented in this paper initially entails the utilization of two separate analytical methodologies to segregate and analyze various channel segments in terms of fish habitat, fish populations, and sensitivity to assorted inputs from land management practices. The results of this check-and-balance approach, in combination with the spatial correlation to hazard zones, provide a systematic procedure to identify and mitigate potential causal impacts to fish habitat and water quality. We assert that our findings support the hypotheses posed in the introduction: 1) that a Geographic Information System (GIS)-based hierarchical ecoclassification can be used to delineate groups of channel segments that exhibit similar characteristics in terms of fish habitat, fish distribution, and sensitivity to land management activities, and 2) that these geomorphic guilds can be used as a template for the extrapolation of the results of watershed analysis to provide for the effective protection of aquatic resources. This study and its subsequent application should address the concerns of Imhof et al. (1996), who conclude that, "Managers must be able to determine where important habitat occurs within a watershed and ideally determine how and why changes of land use will modify habitat. Cause-response information is extremely important for input into land-use planning and ecosystem restoration. Standardized methodologies exist for fish habitat assessment, whereas tools to assist in determining the impact of human disturbances, scale of controlling impact, and their cause-response relationships are limited."

Development and implementation of best management practices (BMP's) and streamside

management zones (SMZ's) are the most common resource protection measures advocated and administered by state regulatory agencies. These measures likely provide adequate protection of aquatic resources under numerous circumstances. However, BMP's and SMZ's are based on the notion that the application of one set of techniques will be appropriate for all circumstances. From our experience conducting watershed analysis, it appears that this notion is erroneous for at least some situations.

Effective management is dependent on knowledge of site-specific conditions. As discussed earlier, watershed analysis has been used as a tool to define site-specific conditions so that appropriate management options can be prescribed. A dual set of management objectives are pursued to maximize both commodity production and aquatic resource protection. Figure 11 displays a cost-benefit interaction between competing objectives. Intensive watershed analysis across an entire landscape is likely to provide optimal resource protection through the acquisition of site-specific knowledge, thus minimizing risk of impacts. Watershed analysis, however, is an expensive and time consuming process. Hence, the cost of acquisition of comprehensive knowledge is likely to be cost prohibitive. Conversely, relatively little local knowledge is required to apply state-mandated protection programs. Since by-the-book regulatory scenarios do not account for all of the inherent variation across a landscape, risk of impact to aquatic resources may be relatively high in some areas, while in others the regulatory standards impose management restrictions in excess of what is needed to protect habitat. The approach developed here, ecoclassification and extrapolation, is intended to optimize the balance between objectives.

This framework is expected to minimize risk by providing a predictive capability of defining site-specific circumstances, while, at the same time, minimizing costs by eliminating the need to conduct comprehensive watershed analysis across the landscape. The strategy adopted by federal agencies (Thomas and Raphael 1993, USDA Forest Service and USDI Bureau of Land Management 1995, USDA Forest Service 1995) is consistent with the paradigm (Figure 11), except that for the federal approaches, one must substitute the *KNOWLEDGE* continuum with the degree (or area) to which management activities are precluded and the *COST* relationship must be viewed as the opportunity cost of restricting management options in affected areas. The efficacy of the federal approach may be appropriate for federal lands, but that decision is derived through both a political process and a limited scientific process that minimizes perceived risk to resources. Giles and Nielsen (1992) state that, "We have never been content with conventional impact assessment ... because it presumes a proposal for change has been made and a site selected. Fisheries managers then sense that there will be undesirable consequences, but do not know what they are. In defense, they may seize upon any strategy, supposition or data to cancel or delay the project. The result is conflict, frustration, and sub-optimal resource use." The federal approach is unlikely to be accepted by land managers charged with economically beneficial utilization of commodity resources. Additionally, the federal approach does not allow for silvicultural management to achieve: 1) maximal yield per unit area, 2) forest stand structural characteristics designed to accomplish specific objectives for ecological purposes (i.e.,

recruitment of LWD of a certain size or species, development of edge habitats, or maintaining cover/forage ratios), and 3) minimization of wildfire and/or disease risk.

In addition to providing for what we will believe will be enhanced site-specific protection of aquatic resources, we expect that our classification approach will prove to be effective for the development of habitat and/or water quality "targets", especially after beta-testing predictive capability (see Effectiveness Monitoring). Lotspeich (1980) opines that , "There is no doubt that streams can be classified in a hierarchy of watershed types that will permit them to appear in groups or classes, and thus simplify assessment of stream quality." We believe that once habitat targets are defined (in terms of central tendency and variance), the data can be used to describe statistically credible criterion for the evaluation of resource "condition," and hence, determining if a measured parameter is within the expected range for a given geomorphic setting. This information will be useful in the assessment of land management effects, as well as for the identification of likely areas for restoration. We also expect that our classification and analysis will be useful for predicting the distribution of rare or threatened species in previously unsurveyed areas. For example, bull trout were found to be strongly associated with super guilds 2, 5, and 8. The spatial distribution of these super guilds can be used as a coarse filter for the identification and prioritization of stream reaches for presence/absence surveys.

The application of the approach that we describe here need not be limited only to those areas where forestry is the predominant land use. We anticipate that the ecoclassification/watershed analysis synthesis approach will be useful in venues more comprehensive than the forest practices/fish habitat example described here. This methodology could as easily be applied to other land management practices such as mining, grazing or agriculture. In addition to using the methodology for the classification and evaluation of habitat elements, it is plausible that application to water quality parameters would be equally productive. Although we are pleased with the stream classification system developed here, it should be noted that all classification systems have strengths and weaknesses. One of the chief purposes of classification is to predict potential management impacts without conducting exhaustive studies on every stream. Our approach is supported by statistical tests of habitat conditions, however, it is possible that other classification systems could be similarly tested and shown to have better (or worse) predictive power with respect to habitat parameters and management impacts.

Finally, we consider the geographic range over which extrapolation should be attempted or justified. Pfister et al. (1977) suggested that an important requisite of any classification system should be definition of the limits of application. Even though we limited our study area to the Swan River basin, we expect that the patterns and relationships developed will be directly applicable to adjacent watersheds exhibiting similar combinations of climate, geology, geomorphic processes, and vegetation. Bryce and Clarke (1996) state that, "As a framework for research and planning, ecoregions provide a natural complement to drainage basins. Both basin and ecoregions should be employed to adequately explore spatial patterns and management

options. Spatial differences in landscape characteristics, ecosystems, or environmental resources are not often partitioned by topographic divides."

We postulate that an applicable area delineating the extent of reliable extrapolation would be at some mid-level in a hierarchical landscape classification scheme. This area, which we refer to as the *meta-ecoterra zone*, should be small enough to accurately capture, classify, and predict (with some degree of statistical confidence) the array of causative influences upon aquatic habitats at the scale of stream reach or valley-bottom type, while at the same time be broad enough to maximize effectiveness of fiscal resources committed to the investigation. Nesser et al. (1997) have recently described regional and subregional ecological units (called sections and subsections, respectively) for the US Forest Service Northern Region. The distribution of these units is identified by the hierarchical integration of physical and biological components that include climate, geomorphology, geology, soils, hydrology, and vegetation. We suggest that *sections*, as described in Nesser et al. (1997), comport with our concept of the meta-ecoterra zone, and may serve as the appropriate sector for investigation and subsequent extrapolation.

By synthesizing knowledge gained through intensive watershed analysis with ecological classification of larger areas, and by using the ecoclassification as a template for extrapolation. we believe that we have provided a puissant instrument for guiding land management decisions resulting in both economic and ecologic benefits. Hynes (1975) states that, "We must, in fact, not divorce the stream from its valley in our thoughts at any time. If we do we lose touch with reality." Given the results of this investigation, we emphatically agree.

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Table 1. Description of guilds within the Swan River basin.

Guild Number	Guild Code	Description
1	MS3A CO1 LTC7	13-39% valley slope, small and large boulder substrate, subalpine fir habitat types, first and second order channels, ground moraine landtype.
2	MS3A CO1 LTC6	13-39% valley slope, small and large boulder substrate, subalpine fir habitat types, first and second order channels, glacial basin landtype.
3	MS4A CO1 LTC6	13-39% valley slope, bedrock sudstrate substrate, subalpine fir habitat types, first and second order channels, glacial basin landtype.
4	MS3B CO1 LTC7	13-39% valley slope, small and large boulder substrate, grand fir and western redcedar habitat types, first and second order channels, ground moraine landtype
5	MS5A CO2 LTC7	13-39% valley slope, undifferentiated substrate, subalpine fir habitat types, third and fourth order channels, glacial basin landtype.
6	MS3A CO1 LTC13	13-39% valley slope, small and large boulder substrate, subalpine fir habitat types, first and second order channels, glacial trough landtype.
7	NL2A CO2 LTC13	2-4% valley slope, gravel/cobble substrate, subalpine fir habitat types, third and fourth order channels, glacial trough landtype.
8	NL2A CO1 LTC7	2-4% valley slope, gravel/cobble substrate, subalpine fir habitat types, first and second order channels, ground moraine landtype.
9	NL1A CO2 LTC7	2-4% valley slope, clay/silt/sand substrate, subalpine fir habitat types, third and fourth order channels, ground moraine landtype.
10	NL1A CO1 LTC7	2-4% valley slope, clay/silt/sand substrate, subalpine fir habitat types, first and second order channels, ground moraine landtype.
11	NL1E CO1 LTC7	2-4% valley slope, clay/silt/sand substrate, willow and sedge habitat types, first and second order channels, ground moraine landtype.
12	NL1E CO2 LTC7	2-4% valley slope, clay/silt/sand substrate, willow and sedge habitat types, third and fourth order channels, ground moraine landtype.
13	NL1E CO1 LTC2	2-4% valley slope, clay/silt/sand substrate, willow and sedge habitat types, first and second order channels, wet depression landtype.
14	NL2A CO2 LTC7	2-4% valley slope, gravel/cobble substrate, subalpine fir habitat types, third and fourth order channels, ground moraine landtype.
15	FL2C CO2 LTC8	0-2% valley slope, gravel/cobble substrate, Engelmann spruce habitat types, third and fourth order channels, glacial outwash landtype.
16	FL1C CO2 LTC3	0-2% valley slope, clay/silt/sand substrate, Engelmann spruce habitat types, third and fourth order channels, floodplain landtype.
17	FL2C CO2 LTC3	0-2% valley slope, gravel/cobble substrate, Engelmann spruce habitat types, third and fourth order channels, floodplain landtype.

Table 1. Concluded.

Guild Number	Guild Code	Description
18	FL2C CO2 LTC7	0-2% valley slope, gravel/cobble substrate, Engelmann spruce habitat types, third and fourth order channels, ground moraine landtype.
19	FL2C CO3 LTC3	0-2% valley slope, gravel/cobble substrate, Engelmann spruce habitat types, fifth and sixth order channels, floodplain landtype.
20	FL1C CO3 LTC3	0-2% valley slope, clay/silt/sand substrate, Engelmann spruce habitat types, fifth and sixth order channels, floodplain landtype.
21	SL2B CO2 LTC7	5-12% valley slope, gravel/cobble substrate, grand fir and western redcedar habitat types, third and fourth order channels, ground moraine landtype.
22	SL3A CO1 LTC7	5-12% valley slope, small and large boulder substrate, subalpine fir habitat types, first and second order channels, ground moraine landtype.
23	WS5A CO1 LTC7	2-45% valley slope, undifferntiated substrate, subalpine fir habitat types, first and second order channels, ground moraine landtype.
24	SL2A CO1 LTC6	5-12% valley slope, gravel/cobble boulder substrate, subalpine fir habitat types, first and second order channels, glacial basin landtype.
25	SL2B CO1 LTC7	5-12% valley slope, gravel/cobble boulder substrate, grand fir and western redcedar habitat types, first and second order channels, ground moraine landtype
26	SL2A CO2 LTC7	5-12% valley slope, gravel/cobble boulder substrate, subalpine fir habitat types, third and fourth order channels, ground moraine landtype.
27	SL2A CO1 LTC7	5-12% valley slope, gravel/cobble boulder substrate, subalpine fir habitat types, first and second order channels, ground moraine landtype.

Table 2. Codes and descriptions of habitat and fish variables measured within each guild.

Variable	Code and Description
Bankfull Width	BFW - Width of the bank full channel (feet)
Transect Length	TL - Distance surveyed from beginning to end of transect (feet)
Bankfull Depth	BFD - Depth of the bank-full channel (inches)
Gradient	GRAD - Drop in water surface elevation per unit length of channel (%)
Temperature	TEMP - Water temperature measured at mid-channel (^{o}C)
Habitat type	Description of the morphologic and hydraulic properties of channel geomorphic units - see text (Hawkins et al. 1993)
Wetted Width	WW - Mean width of each habitat unit measured across the wetted channel perpendicular to the flow (feet)
Habitat Length	HL - Length of each habitat unit measured at the center of the wetted channel (feet)
Non-pool Depth	NPL - Maximu depth of each non-pool habitat unit measured at the center of the wetted channel (inches)
Pool Depth	MPD - Maximum depth of each pool habitat unit (inches)
Tailcrest Depth	TCPD - Maximum depth at the point where the tail of the channel forming each pool habitat unit reaches its hightest elevation (inches)
Dominant Substrate	DS - Description of the particles that constitute the majority of the streambed (Platts et al. 1983)
Substrate Embeddedness	EMB - Score representing the degree to which dominanat substrate particles are embedded in the streambed (Weaver and Fraley 1991)
Wood Cover	PWD - Percentage of the wetted surface area of a habitat unit that is covered by large woody debris (LWD) (%)
Surface Fines	PSF - Percentage of the wetted streambed surface area within a habitat unit that is comprised of substrate materials <2 mm (%)
Undercut Banks	PUC - Percentage of the total streambank at the perimeter of each habitat unit that is undercut (%)
Vegetation Overhang	VO - Percentage of the water surface area in a habitat unit that is shaded by vegetation within 30.5 cm of the water surface (%)
Canopy Cover	CN - Percentage of the water surface area in a habitat unit shaded by trees and shrubs that hang over the stream at > 30.5 cm above the water surface (%)
Channel Migration Zone	CMZ - Estimated extent of potential lateral channel migration - see text (feet)
LWD Diameter	DLWD - Mid-point diamater of each piece of LWD - see text (centimeters)
LWD Length	LLWD - Length of each piece of LWD - see text (meters)

Table 2. Concluded.

Variable	Code and Description
Jam Height	JAMH - Height of each LWD jam (meters)
Jam Length	JAML - Length of each LWD jam (meters)
Jam Width	JAMW - Width of each LWD jam (meters)
Riparian Vegetation	RV - Code of description of dominant vegetation along the banks (Platts et al. 1987)

Table 3. Codes and descriptions of habitat and fish variables compiled for analysis within each guild. Asterisks (*) identifies variables that were used in multivariate analyses. Those without asterisks correlated with other variables or were missing data.

Code	Description
BFW	Bankful width (feet)
BFD	Bankful depth (inches)
*GRAD	Stream gradient (%)
TEMP	Temperature (^{o}C)
THBAR	Total surface area sampled (feet^2)
TPLAR	Total pool area sampled (feet^2)
PPLAR	Percent pool area sampled (%)
*MNWW	Mean wetted width (feet)
*NPLMDP	Mean depth non-pool habitats (inches)
CVNPD	Coefficient of variation of non-pool habitat depth
XDPRPD	Mean residual pool depths (inches)
CVRPD	Coefficient of variation of residual pool depths
*LVLSDS	Number of levels of dominant substrates recorded
MODDSB	Mode of dominant substrate
MODEMB	Mode of embeddedness
XDPRWIW	Mean residual pool depths with wood (inches)
XDPRWOW	Mean residual pool depths without wood (inches)
XPERWD	Mean percent wood in all habitats (%)
XPWPH	Mean percent wood in pool habitats (%)
*XPBLDR	Mean percent boulder in all habitats (%)
*XPSF	Mean percent surface fines in all habitats (%)
XPUC	Mean percent undercut bank in all habitats (%)
*XPVO	Mean percent vegetative overhang in all habitats (%)
*XPCN	Mean percent canopy cover in all habitats (%)
*HUCW	Number of habitat units per channel width
TOTCW	Total number of all wood per channel width
*TNFWCW	Total number of functional wood per channel width

Table 3. Concluded.

Code	Description
CWPJ	Channel widths per jam
RTOTFXN	Ratio of all wood to functional wood
XVOLALL	Mean volume of all wood (meters^3)
XVFW	Mean volume of functional wood (meters^3)
*XJV	Mean jam volume (meters^3)
*XCMZ	Mean channel migration zone (feet)
*CVCMZ	Coefficient of variation of channel migration zone
3	All fish between 0 and 3 inches (fish/100 m^2)
*6	All fish between 3 and 6 inches (fish/100 m^2)
*9	All fish between 6 and 9 inches (fish/100 m^2)
12	All fish between 9 and 12 inches (fish/100 m^2)
*>12	All fish larger than 12 inches (fish/100 m^2)
*BL	Bull trout (fish/100 m^2)
*CT	Cutthroat trout (fish/100 m^2)
*BK	Brook trout (fish/100 m^2)
*RB	Rainbow trout (fish/100 m^2)
*WF	Mountain whitefish (fish/100 m^2)
ALL	Sum of all fish in sites (fish/100 m^2)

Table 4. Statistical summary of habitat and fish variables among 26 guild types (Table 1). The F-ratio is based on one-way ANOVA; similarity among guilds is based on the Newman-Keuls multiple-comparison test.

Variable	F-Ratio	Sign. (P)	Groupings of similar guilds (order is based on ascending mean quantity)
BFW	4.38	0.000	(4,25,1,11,13,27,10,8,21,3,6,9,2,22,24,12,26) (14,16,7,15,17,5,18) (19,20)
BFD	1.71	0.032	(4,1,11,3,10,6,27,8,26,21,9,2,25,24,22,13,12,15,14,20,17,16,18,19,5,7)
GRAD	8.04	0.000	(16,20,15,13,12,19,18,11,9,17,8,14,7,10,5) (26,27,21,25,24,22,4) (2,3,1,6)
TEMP	2.56	0.001	(3,24) (6,4,25,1,2,26,15,21,10,7,22,13,9,5,17,12,18,16,11,8,27,20,14) (19)
MNWW	4.48	0.000	(11,4,1,27,3,6,2) (10,25,8,13,22,24,21,9,26,14,12,7,15,16,5,17,18) (20,19)
PPLAR	1.33	0.158	(13,19,11,1,20,16,8,27,10,6,3,4,2,24,22,14,18,9,15,21,12,25,26,17,5,7)
THBAR	3.25	0.000	(11,4,1,6,27,3,25,2,10,22,8,21,24,13,26,9,7,12,15,14,16,5,17,18) (20,19)
TPLAR	2.79	0.000	(11,4,1,27,6,2,3,8,25,22,10,13,24,9,21,19,14,26,16,18,15,20,12,5,7) (17)
NPLMDP	2.56	0.000	(3,4,5,1,21,2,8,9,24,11,27,7,25,26,15,19,18,22,14,10,12,20,5,16,17,13)
CVNPD	1.54	0.072	(13,5,8,10,6,25,17,22,24,26,16,18,7,11,12,21,1,3,19,9,15,2,27,4,20,14)
XDPRPD	2.69	0.000	(11) (4,8,13,3,6,27,22,1,2,9,24,21,10,16,18,26,20,14,25) (19,5,15,12,7,17)
CVRPD	0.92	0.583	(19,13,11,12,10,14,16,26,15,2,18,21,6,5,25,22,17,7,1,3,4,24,27,9,8,20)
XDPRWIW	2.49	0.001	(13,11) (4,27,8,3,6,9,1,2,22,16,10,21,26,20,18,14,24,17,25,12) (5,19,15,7)
XDPRWOW	0.88	0.625	(11,10,15,3,12,8,4,21,19,27,16,13,22,24,6,26,1,5,18,17,9,20,7,25,2,14)
LVLSDS	2.73	0.000	(13) (16,14,11,19,8,10,18,3,12,9,17,1,15,4,20,5,27,21,6,7,26,24) (22,2,25)
MODDSB	5.90	0.000	(2,25,6,22,21,26,14,24,3,5,20,7,19) (18,15,1,27,17,10,12,9,16,4) (8,13,11)
MODEMB	4.07	0.000	(13,11,8) (10,16,4,22,25,9,5,17,12,18,7,1,27,20,26,2) (19,3,15,14,24,21,6)
XPERWD	0.50	0.976	(24,19,13,14,2,9,22,20,12,17,6,10,18,25,4,3,21,15,26,8,27,1,7,11,5,16)
XPWPH	0.69	0.858	(13,11,6,24,2,1,12,10,16,3,14,4,22,25,9,17,19,8,21,15,27,18,26,5,7,20)

Table 4. Continued.

Variable	F-Ratio	Sign. (P)	Groupings of similar guilds (order is based on ascending mean quantity)
XPBLDR	2.79	0.000	(13,11,16,20,12,8,9,19,17,10,18,15,4,27,2,1,7,25,5,3,22,14,24,21 6,26)
XPSF	6.55	0.000	(2,6,3,14,24,22,21,19,18,26,15,7,5,17,25,27,20) (1,12,9,4,10,16) (8,11,13)
XPUC	1.00	0.474	(2,24,3,19,14,22,6,7,20,27,5,10,18,15,8,16,9,17,21,1,4,25,13,26,11,12)
XPVO	2.42	0.00	(19,21,15,20,6,5,22,2,3,18,25,17,26,24,7,9,1,14,4,16,27,8,12,10,13) (11)
XPCN	6.45	0.000	(13,20,12,19,17,16) (18,24,10,2,9,14,5,26,11,8,3,7,15,27,25) (4,1,22,21,6)
HUCW	3.08	0.000	(13,11) (4,27,8,1,10,12,25,9,3,16,14,15,17,19,21,5,24,7,26,18) (20,6,22,2)
TOTCW	2.48	0.001	(13,4,11) (1,10,25,9,27,12,21,3,6,17,19,24,15,14,8,22,26,16,2,5) (7,18,20)
TNFWCW	2.47	0.001	(13) (4,11,1,10,25,9,27,21,12,3,6,17,19,24,15,14,8,22,26,2,16,5,7,18) (20)
CWPJ	1.04	0.423	(13,2,3,22,1,12,18,10,7,26,25,24,19,21,20,17,8,5,9,15,14,16,27,6,4,11)
RTOTFXN	1.87	0.015	(13) (15,16,6,11,25,4,2,5,1,21,26,9,7,17,24,22,8,27,18,3,12,20,19,14,10)
XVOLALL	2.42	0.001	(13,11) (10,4,6,8,9,26,3,24,21,12,25,2,1,17,19,27,22,18,7,16,15) (5,20,14)
XVFW	2.50	0.001	(13,11) (10,4,6,8,9,26,24,21,2,3,25,12,1,19,27,17,22,18,7,15,16) (5,20,14)
XJV	2.13	0.003	(13,11,2,10,27,8,25,3,22,6,24,1,26,4,16,9,19,21,18,17,14,15,7,12,5) (20)
XCMZ	2.95	0.000	(1,24,3,21,2,25,6,22,26,14,27,4,15,5,10,17,12,7,20,18,19,8,9,13,11,16)
CVCMZ	2.50	0.001	(16,13,9,8,20,11,18,10,15,19,12,21,22,7,3,17,27,25,4,24,5,26,1,14,2,6)
All Fish	1.39	0.129	(1,3,4,2,24,26,21,6,10,25,17,7,20,5,12,13,8,19,16,22,15,18,27,9,14,11)
3 in. fish	1.82	0.019	(1,2,4,3,26,6,24,25,20,21,7,5,16,22,10,17,12,19,8,9,15,13,18,27,14) (11)
6 in. fish	0.84	0.686	(1,3,24,4,2,26,17,10,21,13,18,15,6,12,8,19,7,25,5,16,20,22,27,11,14,9)
9 in. fish	1.55	0.065	(1,4,2,13,3,20,27,10,25,12,24,8,17,18,26,21,7,6,11,19,9,15,5,14,16,22)
12 in. fish	1.64	0.043	(1,2,27,4,25,6,10,11,13,8,3,12,26,24,21,17,9,7,5,19,22,20,18,15,14) (16)

Table 4. Concluded.

Variable	F-Ratio	Sign. (P)	Groupings of similar guilds (order is based on ascending mean quantity)
Fish >12 in.	1.34	0.155	(1,2,3,4,17,13,7,8,10,27,11,12,26,25,22,19,21,5,18,16,6,24,20,14,9,15)
Bull	2.34	0.001	(1,2,3,4,27,6,24,19,11,12,20,22,8,16,9,13,7,25,10,26,14,5,21,15,17) (18)
Cutthroat	2.14	0.004	(1,13,11,20,8,25,19,12,16,3,10,17,15,4,9,2,26,21,24,18,5,27,7,14,6) (22)
Brook	1.73	0.029	(1,2,3,4,24,6,22,21,26,7,20,17,5,10,14,25,18,19,12,15,13,16,8,27,9) (11)
Rainbow	1.15	0.308	(1,2,3,4,22,6,12,8,10,26,11,27,13,24,25,21,15,9,14,16,5,19,17,20,18,7)
Whitefish	1.29	0.189	(1,2,3,4,5,6,7,8,9,10,11,12,13,27,26,21,22,25,24,17,15,18,16,19,20,14)

Table 5. Results of K-means cluster analysis on grouping similar guild types into super guilds. Refer to Table 1 for description of guild types.

Super-Guilds	Description
1	NL1A-1-7, NL1E-2-7, NL1E-1-2, FL1C-2-3
2	MS5A-2-7, NL2A-2-13, FL2C-2-3, FL2C-2-7, FL2C-3-3
3	MS3A-1-7, MS3A-1-6, MS4A-1-6, MS3B-1-7, MS3A-1-13, SL2A-1-6, SL2B-1-7, SL2B-2-7, SL2A-2-7
4	NL2A-1-7, NL1A-2-7, NL1E-1-7, SL2A-1-7
5	NL2A-2-7, FL2C-2-8
6	SL3A-1-7
7	FL1C-3-3

Table 6. Summary of watershed analysis modules (adapted from WFPB, 1995).

Analysis Module	Watershed Input/Process	Typical Potential Forest Management Impacts
Mass Wasting	Coarse and fine sediment	Landslides triggered by improper road construction, temporarily reduced post-harvest root strength
Surface Erosion	Fine sediment	Sheetwash & rainsplash erosion of soil exposed on road tread and cut slopes
Hydrologic Change	Peak streamflow	Peak flow augmentation caused by reduced forest canopy
Riparian Function	Large woody debris recruitment, stream shade	Harvest in riparian stands reducing shade and LWD recruitment
Stream Channel	Fluvial geomorphic processes and watershed geology and hydrology as they relate to channel morphology and potential habitat conditions	Morphologic change associated with loss of LWD, increased coarse sediment, and confinement by valley-bottom roads
Fish Habitat	Existing fish habitat quantity and quality for spawning and rearing (summer & winter)	Impairment of spawning habitat by excess sediment, impairment of rearing habitat by loss of LWD and off-channel habitat, excess sedimentation

Table 7. Channel morphologic classes and corresponding channel slope classes defined by Montgomery and Buffington (1997).

Channel Morphology	**Typical Slope Range (%)**
Pool-riffle	$s \leq 1.5$
Plane-bed	$1.5 < s \leq 3$
Step-pool	$3 < s \leq 6.5$
Cascade	$6.5 < s$

Table 8. GCU characteristics, Goat-Squeezer-Piper watersheds, Swan Valley, Montana. Flow classes are perennial or intermittent/ephemeral. Stream power index is the product of mean channel gradient and mean bankfull depth (cm), and is a relative indicator of sediment transport capacity; it can be converted to total boundary shear stress using constants for density of water and acceleration due to gravity. "- -" indicates no data.

GCU	% of Channel Length	Morphology	Flow	Slope (%)	Channel Confinement	Bankfull Width (ft)	Bankfull Depth (ft)	Lowest Terrace Height (ft)	Average Adjacent Hillslope (%)	LWD Load	Channel Migration Zone	Stream Power Index
1. Swan Floodplain	0.5	Pool-riffle	Per.	1.5	Unconfined	36	1.5	2.8	0	Moderate	Modest	0.7
2. Entrenched Mainstem	6	Forced pool-riffle & Plane bed	Per.	1.9	Moderate	25	1.8	2.8	19	High	Modest	1.0
3. Low-gradient Pool-riffle	1.5	Pool-riffle	Per.	0.9	Unconfined	28	1.5	2.3	0	Low	Significant	0.4
4. Moderate-gradient Avulsing	3	Forced pool-riffle & Step-pool	Per.	3.6	Moderate	24	1.6	2.5	43	High	Significant	1.8
5. Braided Floodplain	2	Braded & FPR & SP	Per.	2.2	Moderate/ Unconfined	25	1.3	2.0	18	High	Significant	1.0
6. Glacial Trough/ Incised Mainstem	11	Step-pool	Per.	7.9	Confined	20	1.6	2.0	58	Mod. Low	None	3.7
7. Ground Moraine Intermittents	18	Variable	I/E & Per.	<1 to >20	Variable	Variable	Variable	Variable	Variable	--	Probably minimal	Low
8. Scarp-slope Headwaters	10	Step-pool & Cascade	Per. & I/E	>20	Confined	--	--	--	--	--	--	Substantial but no delivery
9. Cirque Headwaters	19	Cascade & Step pool,	Per.	4-20	Confined	9	1.6	--	--	Mod. Low	Minimal	Mod. High & delivering
10. Headwaters w/ Avalanche	24	Cascade	I/E	>>20	Confined	--	--	--	--	Unknown-Moc. Low?	Minimal	High & delivering
11. Fans	0.7	Variable	I/E & Per.	2-20	Variable	--	--	--	--	Moc. Low?	Modest	Variable
12. Trough-wall Cascades	3	Cascade	I/E & Per.	8-20+	Confined	--	--	--	--	Moc. Low?	None	High & delivering
13. Upper Glacial Trough Alluvial	0.7	Forced pool-riffle & Plane bed	Per. & I/E	2.5	Moderate	24	1.8	2.5	45	Mod. Low	Modest	1.4

Table 9. Goat/Squeezer and Piper creeks physical channel sensitivity. These sensitivity ratings are modified as warranted by the fish habitat assessment when physical criteria are superseded by biological criteria.

GCU	Coarse Sediment	Fine Sediment	Peak Flows	LWD	Riparian Vegetation	CMZ
1--Swan Floodplain	Moderate	Low	Low/Mod.	Moderate	Low/Mod.	Moderate
2--Entrenched Mainstem	Mod./High	Low	Moderate	High	Moderate	Moderate
3--Low-gradient Pool-riffle	High	Moderate	Moderate	High	Mod./High	Moderate
4--Moderate-gradient Avulsion	Mod./High	Low/Mod.	Moderate	High	Mod./High	High
5--Braided Floodplain	High	Moderate	Moderate	High	Mod./High	High
6--Glacial Trough/Incised Mainstem	Low/Mod.	Low	Low	Low/Mod.	Low	Low
7--Ground Moraine Intermittents	Low/High*	Low/High*	Moderate	Moderate	Mod./High	Low
8--Scarp-slope Headwaters	Moderate	Low	Low/Mod.	Moderate	Low/Mod.	Low
9--Cirque Headwaters	Low/Mod.	Low/Mod.	Low/Mod.	Low	Low	Low/Mod.
10--Headwaters with Avalanche	Moderate	Low	Moderate	Moderate	Moderate	Low
11--Fans	Moderate	Low	Moderate	Moderate	Moderate	Mod./High
12--Trough-wall Cascades	Low	Low	Low	Low	Low	Low
13--Upper Glacial Trough Alluvial	Mod./High	Low./Mod.	Moderate	High	Moderate	Moderate

* Denotes unusual channel conditions where perennial and/or long-duration intermittent flow occurs--salmonids have been observed infrequently in this GCU; most channels in this GCU ephemeral or non-channeled swales where there is insignificant flow and no downstream routing.

Table 10. Cross-tabulation of guilds sampled during watershed analysis and GCU's assigned to survey sites.

Super Guild No	Guilds Sampled	No. Surveyed	GCU's With Mean Gradient < 5 %					GCU's With Mean Gradient > 5 %			
			2	3	4	5	13	6	9	10	11
2	FL2C-2-7	5	3	1	1						
	FL2C-2-3	4	3	1							
	MS5A-2-7	2				2					
3	MS3A-1-7	1						1			
	MS3B-1-7	1									1
	MS4A-1-6	2							1	1	
	SL2B-1-7	2						2			
4	NL2A-1-7	1									1
	SL2A-1-7	2						2			
5	NL2A-2-7	4	2		1		1				
8	SL2A-2-7	5			3			2			
	SL2B-2-7	3			2			1			
Total	12	32	8	2	7	2	1	8	1	1	2

Table 11. Summary of selected characteristics of super GCU's. The first three super GCU's are those that were commonly used by fish. In this group of three, mean slope was significantly different (ANOVA, $P<10^{-7}$). The last two are rarely, if ever, used by fish.

Super GCU's (GCU #'s)	Channel Length (%)	Mean Slope (%)	95% Confidence Interval for Mean Slope	Channel Morphology Predicted for Interval
Ground Moraine (1, 2, 3)	8	1.7	1.4--2.1	Pool-riffle and plane bed
Mountain Front (4, 5)	5	3.0	2.3--3.7	Plane-bed and step-pool
Alpine Glacial Trough (6, 9, 12)	33	7.5	5.5--9.6	Step-pool and cascade
Avalanche and Fan (10, 11)	25	2-20+	n.a.	Predominantly Cascade
Intermittents (7, 8)	28	2-20+	n.a.	Variable

Table 12. Results of K-means cluster analysis and watershed analysis on grouping similar guild types into super guilds. Refer to Table 1 for description of guild types.

Super-Guilds	Description
1	NL1A-1-7, NL1E-2-7, NL1E-1-2, FL1C-2-3
2	MS5A-2-7, NL2A-2-13, FL2C-2-3, FL2C-2-7, FL2C-3-3
3	MS3A-1-7, MS3A-1-6, MS4A-1-6, MS3B-1-7, MS3A-1-13, SL2A-1-6, SL2B-1-7
4	NL2A-1-7, NL1A-2-7, NL1E-1-7, SL2A-1-7
5	NL2A-2-7, FL2C-2-8
6	SL3A-1-7
7	FL1C-3-3
8	SL2B-2-7, SL2A-2-7

Table 13. Summary of habitat and fish variables selected with step-wise multiple discriminant analysis to discriminate among eight super guilds in the Swan River basin. The reduction in classification error due to discriminant functions was 60.4%. Variable codes are described in Table 3.

Independent variable	Percent change in Lambda	F-value	Probability level	Wilks' Lambda
GRAD	51.19	18.28	0.000	0.488
XPSF	32.89	8.47	0.000	0.328
XPCN	31.19	7.77	0.000	0.225
CT	20.09	4.27	0.000	0.180
XJV	18.36	3.79	0.001	0.147
LVLSDS	15.58	3.08	0.005	0.124
BK	14.58	2.83	0.009	0.106
MNWW	14.55	2.80	0.010	0.091
XPBLDR	13.76	2.60	0.016	0.078
Fish >12 in.	13.43	2.50	0.019	0.068
BL	13.06	2.40	0.025	0.059
RB	12.69	2.30	0.031	0.051
NPLMDP	11.34	2.01	0.060	0.046

Table 14. Summary of t-test results of differences in habitat and fish variables between disturbed (land-use activities) and undisturbed (no land-use activities) sites within super guilds. Significant differences (P<0.05) are identified as "**Y**" and no difference as "N." See Appendix B for detailed t-test results.

Variable	Super-Guild Type							
	1	2	3	4	5	6	7	8
BFW	N	**Y**	N	N	N	N	N	N
BFD	N	**Y**	N	N	N	N	N	N
GRAD	N	N	N	N	N	N	N	N
TEMP	N	N	N	N	N	N	N	N
THBAR	N	**Y**	N	N	N	N	N	N
TPLAR	N	N	N	N	**Y**	N	N	N
PPLAR	N	N	**Y**	N	**Y**	N	N	N
MNWW	N	**Y**	N	N	N	N	N	N
NPLMDP	N	**Y**	N	N	N	N	N	N
CVNPD	N	N	N	N	N	N	N	N
XDPRPD	N	N	N	N	N	N	N	N
CVRPD	N	N	N	N	N	N	N	**Y**
LVLSDS	N	N	N	N	N	N	N	N
MODDSB	N	**Y**	N	N	N	N	N/A	N
MODEMB	N	**Y**	N	N	N	N	N	N
XDPRWIW	N	N	N	N	N	N	N	N
XDPRWOW	N/A	N	N	N	N	N	N/A	N
XPERWD	N	N	N	N	N	N	N	N
XPWPH	N	N	N	N	N	N	N	N
XPBLDR	N	N	N	N	N	N	N	N
XPSF	N	N	N	N	N	N	N	N
XPUC	N	N	N	N	**Y**	N	N	N
XPVO	N	N	N	N	N	N	N	N
XPCN	N	N	N	N	N	N	N	N
HUCW	N	N	N	N	N	N	N	N

Table 14. Concluded.

Variable	Super-Guild Type							
	1	2	3	4	5	6	7	8
TOTCW	N	N	N	N	N	N	N	N
TNFWCW	N	Y	N	N	N	N	N	N
CWPJ	N	N	N	N	N	Y	N	N
RTOTFXN	N	N	N	N	N	N	N/A	N
XVOLALL	N	N	N	N	N	N	N	N
XVFW	N	N	N	N	N	N	N	N
XJV	N	N	N	N	N	N	N	N
XCMZ	N	N	N	N	N	N	N	N
CVCMZ	N	N	N	N	N	N	N	N
3	N	N	N	N	N	N	N	N
6	N	N	N	N	N	N	N	N
9	N	N	N	N	N	N	N	N
12	N	N	N	N	N	N	N	N
>12	N	N	N	N	N	N/A	N	N
BL	N	Y	N	N	N	N	N	N
CT	N	N	N	N	N	N	N/A	N
BK	N	N	N	N	N	N	N	N
RB	N	N	N/A	N	N	N/A	N	N
WF	N	N	N/A	N/A	N	N/A	N	N/A
ALL	N	N	N	N	N	N	N	N

Table 15. Pearson correlations (r) among independent and dependent variables within super guild 1 (see Table 3 for definitions of codes). Sample size=20.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
GRAD-XPBLDR	0.93	3-BK	0.74	6-TEMP	0.69
TEMP-CWPJ	0.76	6-BK	0.89	6-CWPJ	0.87
THBAR-TPLAR	0.87	9-12	0.96	9-TEMP	0.69
THBAR-MNWW	0.96	9->12	0.85	9-CWPJ	0.95
THBAR-XDPRPD	0.72	12->12	0.84	9-XCMZ	0.46
TPLAR-MNWW	0.84			12-TEMP	0.65
TPLAR-XDPRPD	0.78			12-CWPJ	0.96
TPLAR-XJV	0.70			12-XCMZ	0.52
MNWW-XDPRPD	0.80			>12-TEMP	0.50
MNWW-CVRPD	-0.67			>12-CWPJ	0.74
CVNPD-MODEMB	0.65			>12-XCMZ	0.59
CVNPD-HUCW	0.70			BL-MNWW	0.47
XDPRPD-XPUC	0.71			BL-CVRPD	-0.47
XDPRPD-XJV	0.74			CT-GRAD	0.83
LVLSDS-XPSF	-0.67			CT-MODDSB	-0.61
MODDSB-MODEMB	-0.86			CT-MODEMB	0.46
MODDSB-XPSF	0.96			CT-XPBLDR	0.85
MODDSB-HUCW	-0.72			CT-XPSF	-0.47
MODEMB-XPSF	-0.94			BK-TEMP	0.66
MODEMB-HUCW	0.65			BK-CWPJ	0.85
XPERWD-XPWPH	0.94			RB-CWPJ	0.53
XPERWD-TNFWCW	0.74			WF-CVNPD	0.51
XPSF-HUCW	-0.73			WF-HUCW	0.51
CWJP-XCMZ	0.65			ALL-TEMP	0.67
				ALL-CWPJ	0.87

Table 16. Pearson correlations (r) among independent and dependent variables within super guild 2 (see Table 3 for definitions of codes). Sample size=25.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
GRAD-XPBLDR	0.78	3-BK	0.71	3-GRAD	-0.52
TEMP-PPLAR	-0.60	6-CT	0.61	6-LVLSDS	0.46
THBAR-MNWW	0.97	6-BK	0.64	12-PPLAR	-0.45
TPLAR-PPLAR	0.82	9-BK	0.60	12-MODDSB	-0.44
TPLAR-MODDSB	0.74			>12-PPLAR	-0.43
TPLAR-XPSF	0.64			>12-XPBLDR	0.49
PPLAR-MODDSB	0.65			>12-CWPJ	0.61
LVLSDS-XPCN	0.63			>12-XJV	0.53
MODDSB-MODEMB	-0.63			BL-XPUC	0.44
MODDSB-XPBLDR	-0.68			CT-CVRPD	0.44
MODDSB-XPSF	0.75			CT-XPCN	0.43
MODEMB-XPSF	-0.72			BK-GRAD	-0.40
XPERWD-XPWPH	0.93			RB-CVRPD	0.63
XPERWD-XPSF	0.60			RB-XPUC	-0.53
XPBLDR-XCMZ	-0.65			RB-CVCMZ	0.51
				WF-TEMP	0.66
				WF-THBAR	0.69
				WF-MNWW	0.67
				WF-CVNPD	0.46
				ALL-GRAD	-0.45
				ALL-MNWW	-0.42

Table 17. Pearson correlations (r) among independent and dependent variables within super guild 3 (see Table 3 for definitions of codes). Sample size=35. RB and WF had zero variances.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
THBAR-TPLAR	0.91	3-6	0.77	3-TEMP	0.42
THBAR-MNWW	0.93	3-BK	0.92	3-LVLSDS	0.39
TPLAR-PPLAR	0.67	6-9	0.36	6-TEMP	0.51
TPLAR-MNWW	0.88	6-CT	0.54	6-LVLSDS	0.39
MNWW-XDPRPD	0.69	6-BK	0.79	9-THBAR	0.36
NPLMDP-XDPRPD	0.72	9->12	0.66	9-MNWW	0.38
CVRPD-CWPJ	0.65	9-CT	0.79	9-NPLMDP	0.39
MODDSB-XPSF	0.78	12->12	0.69	9-XDPRPD	0.39
MODEMB-XPSF	-0.72	>12-CT	0.61	9-XPERWD	-0.33
XPVO-XPSF	0.74	BL-9	0.40	9-XVFW	0.33
HUCW-TNFWCW	0.77			12-THBAR	0.36
XJV-CWPJ	0.65			12-MNWW	0.36
				12-XPCN	-0.33
				BK-TEMP	0.45
				BK-LVLSDS	0.39
				ALL-TEMP	0.50
				ALL-LVLSDS	0.40

Table 18. Pearson correlations (r) among independent and dependent variables within super guild 4 (see Table 3 for definitions of codes). Sample size=20. WF had zero variance.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
THBAR-TPLAR	0.67	3-6	0.64	3-TEMP	0.60
THBAR-MNWW	0.89	3-BK	0.95	6-TEMP	0.61
THBAR-XVFW	0.70	6-BK	0.83	6-LVLSDS	0.45
THBAR-XJV	0.92	12->12	0.89	6-HUCW	0.51
TPLAR-MNWW	0.81			9-PPLAR	0.45
TPLAR-XDPRPD	0.69			9-LVLSDS	0.40
PPLAR-LVLSDS	0.71			9-HUCW	0.56
PPLAR-HUCW	0.66			12-XDPRPD	0.39
MNWW-XDPRPD	0.68			12-MODEMB	0.48
MNWW-XJV	0.70			12-XPSF	-0.45
NPLMDP-XPBLDR	0.66			BL-TPLAR	0.78
XDPRPD-MODDSB	-0.70			BL-MNWW	0.52
XDPRPD-XPSF	-0.69			BL-XDPRPD	0.57
CVRPD-CWPJ	-0.61			BL-LVLSDS	0.43
LVLSDS-XPSF	-0.68			BL-XPCN	-0.53
LVLSDS-HUCW	0.73			CT-NPLMDP	0.59
MODDSB-MODEMB	-0.76			CT-XDPRPD	0.55
MODDSB-XPBLDR	-0.75			CT-MODDSB	-0.59
MODDSB-XPSF	0.93			CT-XPBLDR	0.91
MODEMB-XPSF	-0.86			BK-TEMP	0.64
MODEMB-CVCMZ	0.68			RB-THBAR	0.84
XPERWD-XPWPH	0.97			RB-MNWW	0.60
HUCW-XPSF	-0.64			RB-XVFW	0.74
XVFW-XJV	0.81			RB-XJV	0.97
				ALL-TEMP	0.61

Table 19. Pearson correlations (r) among independent and dependent variables within super guild 5 (see Table 3 for definitions of codes). Sampe size=10.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
GRAD-CVCMZ	0.82	3-WF	0.93	3-TEMP	0.81
TEMP-TPLAR	-0.75	6-9	0.72	3-MNWW	-0.60
THBAR-MNWW	0.88	12->12	0.77	6-TEMP	0.79
THBAR-NPLMDP	0.73			6-TPLAR	-0.91
THBAR-HUCW	-0.82			6-MODDSB	-0.64
PPLAR-XPUC	0.76			9-TPLAR	-0.71
PPLAR-HUCW	0.77			9-CVRPD	-0.84
MNWW-NPLMDP	0.73			9-MODDSB	-0.85
CVNPD-XPVO	0.73			9-XPERWD	-0.83
CVNPD-XPCN	-0.84			9-XPWPH	-0.78
CVRPD-MODDSB	0.87			9-XPUC	-0.70
CVRPD-XPERWD	0.79			BL-XDPRPD	0.65
CVRPD-XPWPH	0.75			BL-CWPJ	0.63
CVRPD-XPUC	0.74			CT-CVRPD	-0.60
LVLSDS-XPVO	-0.76			CT-MODDSB	-0.60
LVLSDS-XPCN	0.73			CT-XPBLDR	0.68
MODDSB-XPERWD	0.81			CT-XCMZ	-0.69
XPERWD-XPWPH	0.95			CT-CVCMZ	0.82
XPERWD-XPSF	0.75			RB-THBAR	0.66
XPERWD-XPUC	0.69			RB-MODEMB	-0.78
XPWPH-XPSF	0.71			WF-TEMP	0.91
XPWPH-XPUC	0.76			WF-XPVO	0.61
XPBLDR-XCMZ	-0.69			ALL-TEMP	0.89
XPSF-CVCMZ	-0.71			ALL-TPLAR	-0.67

Table 19. Concluded.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
XPUC-HUCW	0.79				
XPUC-CWPJ	-0.78				
XPVO-XPCN	-0.74				
HUCW-CWPJ	-0.82				

Table 20. Pearson correlations (r) among independent and dependent variables within super guild 6 (see Table 3 for definitions of codes). Sample size=5. RB, WF, and >12 had zero variances.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
GRAD-THBAR	-0.91	6-9	0.95	3-MODEMB	0.82
GRAD-TPLAR	-0.85	6-12	0.96	3-XPVO	0.80
GRAD-MNWW	-0.86	6-CT	0.99	6-CVRPD	0.98
GRAD-XPERWD	-0.89	9-12	0.99	9-CVRPD	0.90
GRAD-XPWPH	-0.88	9-CT	0.94	9-XPUC	0.81
GRAD-TNFWCW	-0.87	12-CT	0.95	12-CVRPD	0.92
GRAD-XJV	-0.96			12-LVLSDS	-0.80
THBAR-TPLAR	0.88			12-XPUC	0.81
THBAR-MNWW	0.98			BL-GRAD	-0.93
THBAR-NPLMDP	0.94			BL-THBAR	0.87
THBAR-XPERWD	0.92			BL-TPLAR	0.97
THBAR-XPWPH	0.94			BL-MNWW	0.86
THBAR-XPSF	0.89			BL-XPERWD	0.96
THBAR-TNFWCW	0.90			BL-XPWPH	0.93
THBAR-XJV	0.93			BL-TNFWCW	0.97
TPLAR-MNWW	0.89			BL-XJV	0.98
TPLAR-XPERWD	0.96			CT-CVRPD	0.97
TPLAR-XPWPH	0.94			BK-GRAD	-0.93
TPLAR-TNFWCW	0.99			BK-THBAR	0.88
TPLAR-XJV	0.95			BK-TPLAR	0.97
PPLAR-MODDSB	-0.92			BK-MNWW	0.86
MNWW-NPLMDP	0.93			BK-XPERWD	0.96
MNWW-XPERWD	0.89			BK-XPWPH	0.93
MNWW-XPWPH	0.90			BK-TNFWCW	0.98
MNWW-XPSF	0.87			BK-XJV	0.98
MNWW-TNFWCW	0.88			ALL-CVRPD	0.97

Table 20. Concluded.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
MNWW-XJV	0.93				
NPLMDP-XPERWD	0.84				
NPLMDP-XPWPH	0.88				
NPLMDP-XPSF	0.93				
NPLMDP-TNFWCW	0.80				
CVNPD-MODEMB	0.91				
XDPRPD-LVLSDS	0.90				
XDPRPD-XPCN	-0.90				
LVLSDS-XPUC	-0.90				
LVLSDS-XPCN	-0.85				
MODDSB-CVCMZ	-0.85				
XPERWD-XPWPH	0.99				
XPERWD-TNFWCW	0.99				
XPERWD-XJV	0.93				
XPWPH-TNFWCW	0.97				
XPWPH-XJV	0.91				
XPBLDR-XCMZ	-0.83				
XPBLDR-CVCMZ	0.87				
XPSF-XPCN	-0.80				
XPSF-HUCW	-0.85				
XPSF-XVFW	0.87				
XPVO-XCMZ	-0.96				
XPCN-XVFW	-0.92				
HUCW-CWPJ	-0.93				
HUCW-XVFW	-0.88				
TNFWCW-XJV	0.94				

Table 21. Pearson correlations (r) among independent and dependent variables within super guild 7 (see Table 3 for definitions of codes). Sample size=5. MODDSB and CT had zero variances.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
GRAD-NPLMDP	0.80	3-BL	0.85	3-PPLAR	0.92
GRAD-XPERWD	-0.81	3-BK	0.92	3-XJV	0.99
GRAD-TNFWCW	-0.86	6-WF	0.89	6-MODEMB	0.90
TEMP-XVFW	0.87	>12-RB	0.86	6-XPWPH	0.81
THBAR-MNWW	0.95	BL-BK	0.98	6-CWPJ	0.89
THBAR-XPWPH	-0.87			6-CVCMZ	0.80
THBAR-CVCMZ	-0.93			9-XPSF	-0.84
PPLAR-XJV	0.92			9-CWPJ	0.92
MNWW-XPWPH	-0.95			12-TEMP	0.90
MNWW-CVCMZ	-0.85			12-TPLAR	0.90
NPLMDP-TNFWCW	-0.95			12-XVFW	0.87
CVNPD-XPWPH	0.99			12-XJV	0.82
CVNPD-XPUC	-0.80			>12-XPUC	0.96
XDPRPD-CVRPD	-0.88			BL-PPLAR	0.80
XDPRPD-XPERWD	-0.82			BL-CVNPD	0.97
XDPRPD-XPSF	-0.98			BL-XPWPH	0.95
XDPRPD-XPCN	-0.86			BL-XJV	0.81
XDPRPD-HUCW	0.92			BK-PPLAR	0.82
CVRPD-XPERWD	0.93			BK-CVNPD	0.93
CVRPD-XPSF	0.84			BK-XPWPH	0.88
CVRPD-XPCN	0.99			BK-XJV	0.89
CVRPD-HUCW	-0.99			RB-THBAR	0.91
CVRPD-XVFW	-0.92			RB-TPLAR	0.94
LVLSDS-XPWPH	-0.95			RB-MNWW	0.91
LVLSDS-CVCMZ	-0.83			WF-XDPRPD	0.85
MODEMB-XPSF	-0.84			WF-MODEMB	0.98

Table 21. Concluded.

Independent-Independent Var.		Dependent-Dependent Var.		Independent-Dependent Var.	
Variables	r	Variables	r	Variables	r
MODEMB-CWPJ	0.80			WF-XPSF	-0.92
MODEMB-CVCMZ	0.88			WF-CWPJ	0.87
XPERWD-TNFWCW	0.91			WF-CVCMZ	0.85
XPWPH-XPUC	-0.84			ALL-CWPJ	0.91
XPWPH-CVCMZ	0.84				
XPBLDR-XPUC	0.82				
XPSF-CWPJ	-0.92				
XPVO-XCMZ	-0.95				
XPCN-HUCW	-0.90				
XPCN-XVFW	-0.85				
HUCW-XVFW	0.94				

Table 22. Pearson correlations (r) among independent and dependent variables within super guild 8 (see Table 3 for definitions of codes). Sample size=10. WF had zero variance.

Independent-Independent Var.		Dependent Dependent Var.		Independent Dependent Var.	
Variables	r	Variables	r	Variables	r
GRAD-PPLAR	-0.70	3-BL	0.80	3-XVFW	0.78
GRAD-CVNPD	0.71	9-CT	0.85	6-GRAD	0.67
THBAR-TPLAR	0.86	12-BK	0.72	12-GRAD	0.65
THBAR-MNWW	0.98			>12-TPLAR	0.67
THBAR-XDPRPD	0.79			>12-XDPRPD	0.75
TPLAR-MNWW	0.86			>12-XJV	0.86
TPLAR-CVNPD	-0.74			BL-XVFW	0.67
TPLAR-XDPRPD	0.86			CT-PPLAR	-0.67
MNWW-XDPRPD	0.82			BK-MODEMB	-0.70
CVNPD-XDPRPD	-0.82			RB-TPLAR	0.67
XDPRPD-XJV	0.76			RB-MNWW	0.62
CVRPD-HUCW	0.74			RB-XDPRPD	0.75
LVLSDS-MODDSB	0.78			RB-XJV	0.86
LVLSDS-XPSF	0.87			ALL-GRAD	0.71
MODDSB-XPSF	0.87			ALL-PPLAR	-0.65
MODEMB-XPSF	-0.85				
XPERWD-XPWPH	0.96				
XPERWD-XPSF	0.80				
XPERWD-XPVO	0.73				
XPWPH-XPSF	0.79				
XPWPH-XPVO	0.81				
XPSF-XPVO	0.73				

Table 23. Goat/Squeezer and Piper creeks fish habitat vulnerability.

GCU	Coarse Sediment	Fine Sediment	Peak Flows	LWD	Riparian Vegetation	CMZ
1--Swan Floodplain	Moderate	Low	Moderate	Moderate	Low	Moderate
2--Entrenched Mainstem	Moderate	Moderate	Moderate	High	Moderate	Moderate
3--Low-gradient Pool-riffle	High	High	Moderate	High	High	Moderate
4--Moderate-gradient Avulsion	High	Moderate	Moderate	High	High	High
5--Braided Floodplain	High	High	Moderate	High	Moderate	High
6--Glacial Trough/Incised Mainstem	Low	Low	Moderate	Moderate	Low	Low
7--Ground Moraine Intermittents	Low/High*	Low/High*	Moderate	Moderate	Mod/High*	Low
8--Scarp-slope Headwaters	Moderate	Low	Low	Moderate	Low	Low
9--Cirque Headwaters	Moderate	Moderate	Low	Moderate	Low/High^	Low/Mod^
10--Headwaters with Avalanche	Moderate	Low	Moderate	Moderate	Moderate	Low
11--Fans	Moderate	Low	Moderate	Moderate	Moderate	Moderate
12--Trough-wall Cascades	Low	Low	Low	Low	Low	Low
13--Upper Glacial Trough Alluvial	High	Moderate	Moderate	High	Moderate	Moderate

* High vulnerability rating applies only to fish-bearing channel segments - usually those rare channel segments in this GCU that exhibit perennial flow.

^ High vulnerability rating applies to unique inclusions of these channel segments exhibiting low gradient (<3%) and small substrate (sand, gravel, small cobble).

Table 24. Cross Tabulation of GCU's, super GCU's and super guilds.

	Ground Moraine			Mountain Front		Alpine Glacial Trough			Intermittents		Avalanche and Fan		
Super Guild	GCU 1	GCU 2	GCU 3	GCU 4	GCU 5	GCU 6	GCU 9	GCU 12	GCU 7	GCU 8	GCU 10	GCU 11	GCU 13
1	X		X										
2		X	X	X	X								
3							X		X				
4						X	X					X	
5		X		X									X
6						X	X						
7	X												
8				X		X							

Table 25. Hypothesized vulnerability table for super guilds.

Super Guild	Coarse Sediment	Fine Sediment	Peak Flow	LWD	Riparian Vegetation	Channel Migration Zones
1	M/H	L/H	M	M/H	L/H	M
2	H	M/H	M	H	M/H	M/H
3	L/M/H	L/M/H	L/M	M	L/M/H	L
4	M	L	M	M	L/M/H	L/M
5	M/H	M	M	H	M/H	M/H
6	L/M	L/M	L/M	M	L/H	L
7	M	L	M	M	L	M
8	L/H	L/M	M	M/H	L/H	L/H

L = Low M = Moderate H = High

Table 26. Final vulnerability table for super guilds. (* indicates a significant inconsistency in vulnerability assignment by extrapolation from GCU's; in these cases, a detailed explanation of the cause and character of the inconsistent vulnerability is presented in the text.)

Super Guild	Coarse Sediment	Fine Sediment	Peak Flow	LWD	Riparian Vegetation	Channel Migration Zones
1	M/H	L/H*	M	M	L/H*	M
2	H	M/H	M	H	M/H	M/H
3	L/M/H*	L/M/H*	L/M	M	L/M/H*	L
4	M	L	M	M	L/M/H*	L/M
5	M/H	M	M	H	M/H	M/H
6	L/M	L/M	L/M	M	L/H*	L
7	M	L	M	M	L	M
8	L/H*	L/M	M	M/H	L/H*	L/H*

L = Low M = Moderate H = High

Table 27. Summary of causal mechanism reports for the Piper and Goat creeks watershed analysis.

CMR #	Watershed Input (Process)	Description
A1	Coarse and fine sediment (mass wasting)	Steep slopes adjacent to streams in two landform units (*Over-steepened Toe Slopes, Inner Gorges*) are identified as having a high landslide potential associated with road construction
A2	Coarse and fine sediment (mass wasting)	Slopes in excess of 80% within the *Steep Rockland* landform unit are identified as having a moderate landslide potential. Because of the high-elevations, and steep rocky slopes in this map unit, few if any trees exist. As such, timber harvest is an unlikely triggering mechanism.
A3	Coarse and fine sediment (mass wasting)	Steep slopes adjacent to streams in two landform units: *Steep Alpine Lands*, and *Deep-Seated Landslides*, are identified as having a moderate mass wasting hazard associated with potential road construction and timber harvest,
A4	Coarse and fine sediment (mass wasting)	Steep slopes adjacent to streams in *Glacial Moraine Deposits with Seep Potential* have a moderate mass wasting potential where roads intercept shallow subsurface flow.
B1	Fine sediment (road erosion)	Similar to CMR A4, roads constructed in areas with significant shallow groundwater flow have the potential for water intercepted by cutslopes to cause ditch erosion and fine-sediment delivery to streams.
B2	Fine sediment (road erosion)	Though fine sediment from roads poses a low hazard overall, opportunities exist to further reduce sediment delivery by applying intensive drainage around some stream crossings. This CMR identifies where these high priority areas are located.
D1	LWD / Solar radiation (riparian harvest)	Channel segments that have had significant historic riparian timber harvest, where high hazards exist for LWD recruitment and water temperature.
D2	CMZ and LWD (riparian harvest)	Channel segments that are moderately-to-highly vulnerable to channel migration, LWD recruitment, or riparian vegetation, where future management could diminish stream function.
D3	LWD (riparian harvest)	Two unsurveyed channel segments in Goat Creek where uncertainty exists about fish presence, and channel vulnerabilities.

Table 28. Matrix used to produce management response (prescriptions) for a given combination of delivered hazard and resource vulnerability (after WFPB 1995).

	Low Probability of Delivered Hazard	**Moderate Probability of Delivered Hazard**	**High Probability of Delivered Hazard**
Low Resource Vulnerability	Standard Rules (SMZ's, BMP's) Apply	Standard Rules (SMZ's, BMP's) Apply	Prevent or Avoid
Moderate Resource Vulnerability	Standard Rules (SMZ's, BMP's) Apply	Minimize	Prevent or Avoid
High Resource Vulnerability	Standard Rules (SMZ's, BMP's) Apply	Prevent or Avoid	Prevent or Avoid

Figures

Figure 1a. Conceptual representation of synthesis process.

Figure 1b. Flowchart depicting cells of synthesis process.

Figure 2. Subsections in the Swan River Basin.

Figure 3. Riparian landtypes in the Swan River Basin.

Figure 4. Distribution of stream order classes in the Swan River Basin.

Figure 5. General landtype classes in the Swan River Basin.

Figure 6. Cumulative guild distribution within the Swan River Basin.

Figure 7. Spatial relationships between super guilds and GCU's in the Goat Creek watershed analysis area.

Figure 8. Spatial relationships between super guilds and GCU's in the Piper Creek watershed analysis area.

Figure 9a. Mean and 95% CI of stream gradients and percent surface fines among eight super guild types in the Swan River Basin, Montana.

Figure 9b. Mean and 95% CI of percent canopy cover and wood jam volume among eight super guild types in the Swan River Basin, Montana.

Figure 9c. Mean and 95% CI of dominant substrate levels and wetted widths among eight super guild types in the Swan River Basin, Montana.

Figure 9d. Mean and 95% CI of percent boulder cover and non-pool depths among eight super guild types in the Swan River Basin, Montana.

Figure 9e. Mean and 95% CI of fish larger than 12 inches and bull trout among eight super guild types in the Swan River Basin, Montana.

Figure 9f. Mean and 95% CI of cutthroat trout and brook trout densities among eight super guild types in the Swan River Basin, Montana.

Figure 9g. Mean and 95% CI of rainbow trout and mountain whitefish densities among eight super guild types in the Swan River Basin, Montana.

Figure 10. Distribution of super guilds within the Swan River Basin.

Figure 11. Conceptual representation of cost/benefits paradigm for natural resources management.

Figure 1a. Conceptual representation of synthesis process.

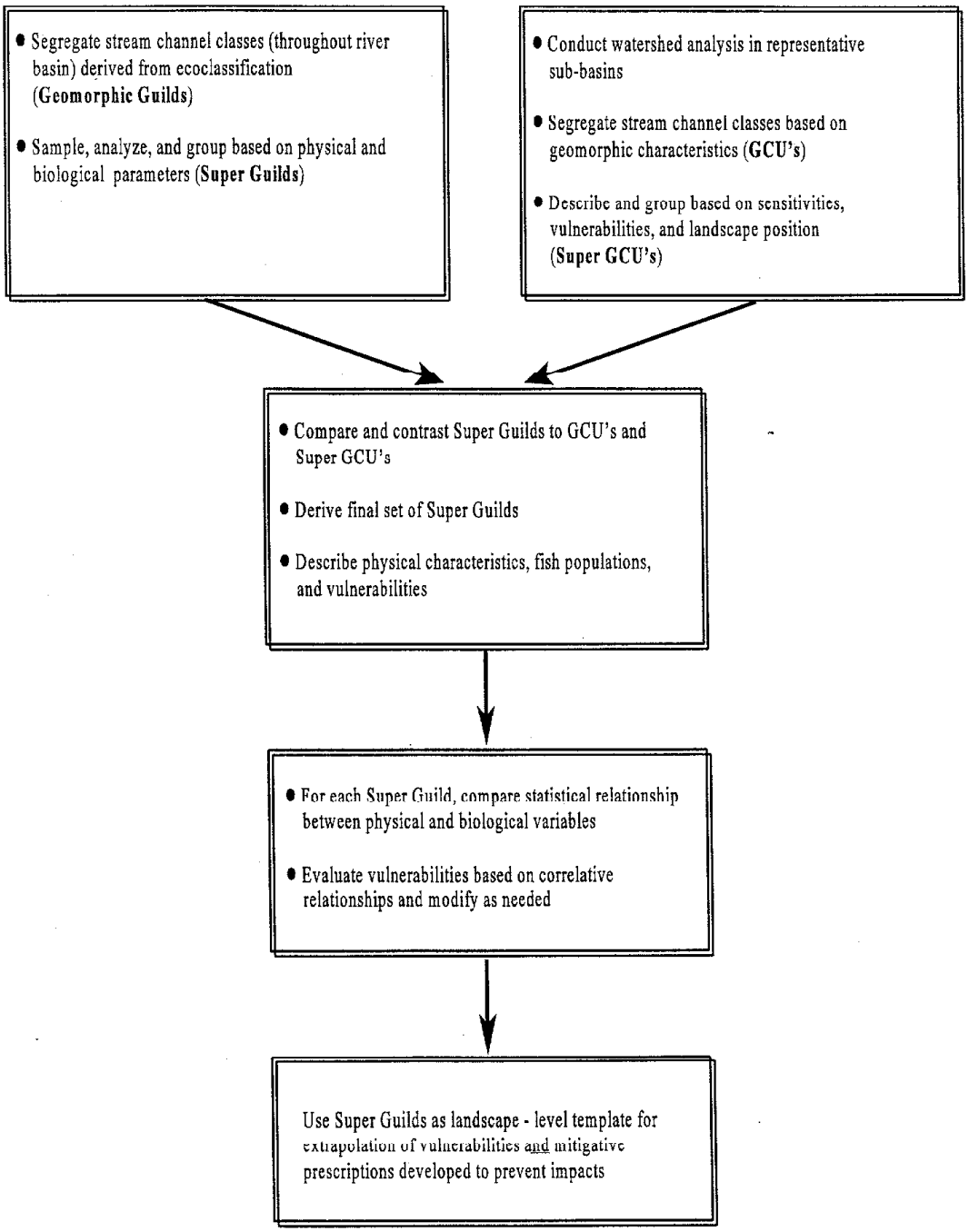


Figure 1b. Flowchart depicting cells of synthesis process.

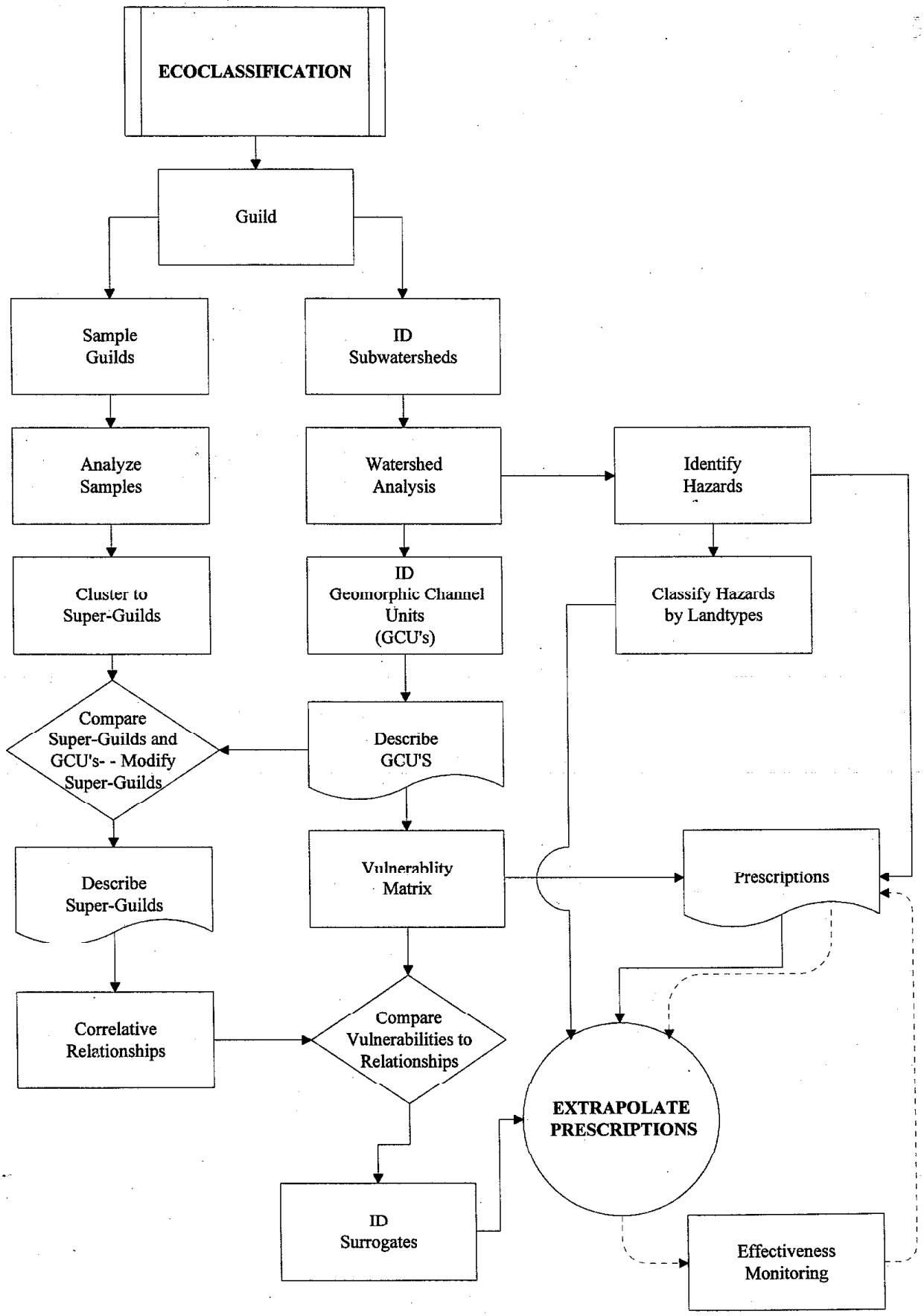
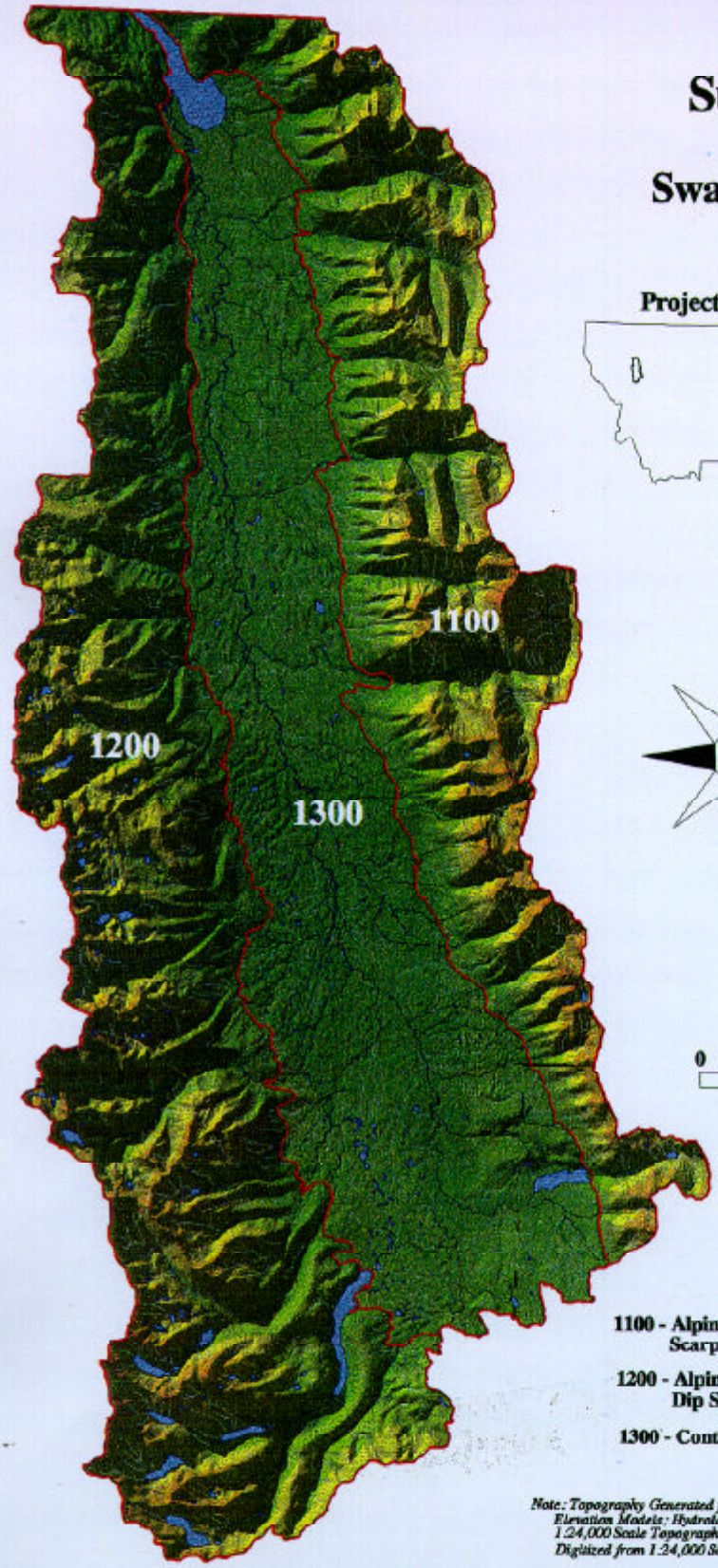
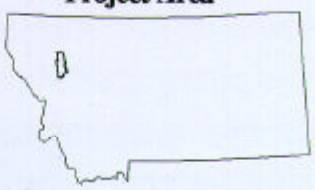


Figure 2

Subsections in the Swan River Basin



Project Area



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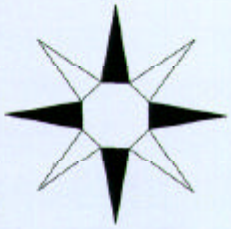


0 5

Miles

1100 - Alpine Glacial Sedimentary Scarp Slope

1200 - Alpine Glacial Sedimentary Dip Slope

1300 - Continental Glacial Valley

Note: Topography Generated from 1:24,000 Scale Digitial Elevation Models; Hydrologic features digitized from 1:24,000 Scale Topographic Maps; Landtype Associations Digitized from 1:24,000 Scale Quads.

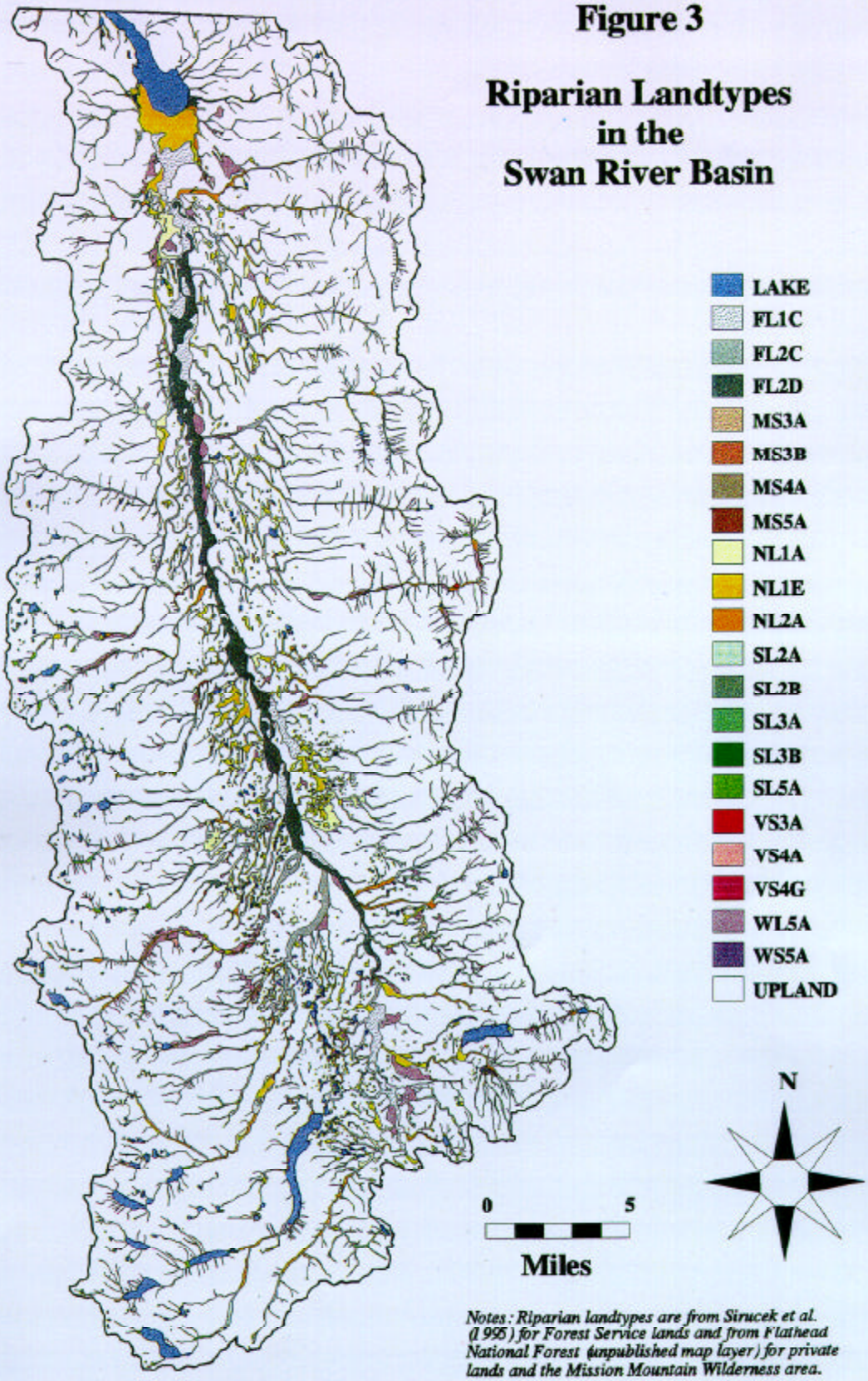


Figure 3

Riparian Landtypes in the Swan River Basin

Notes: Riparian landtypes are from Sirucek et al. (1995) for Forest Service lands and from Flathead National Forest (unpublished map layer) for private lands and the Mission Mountain Wilderness area.

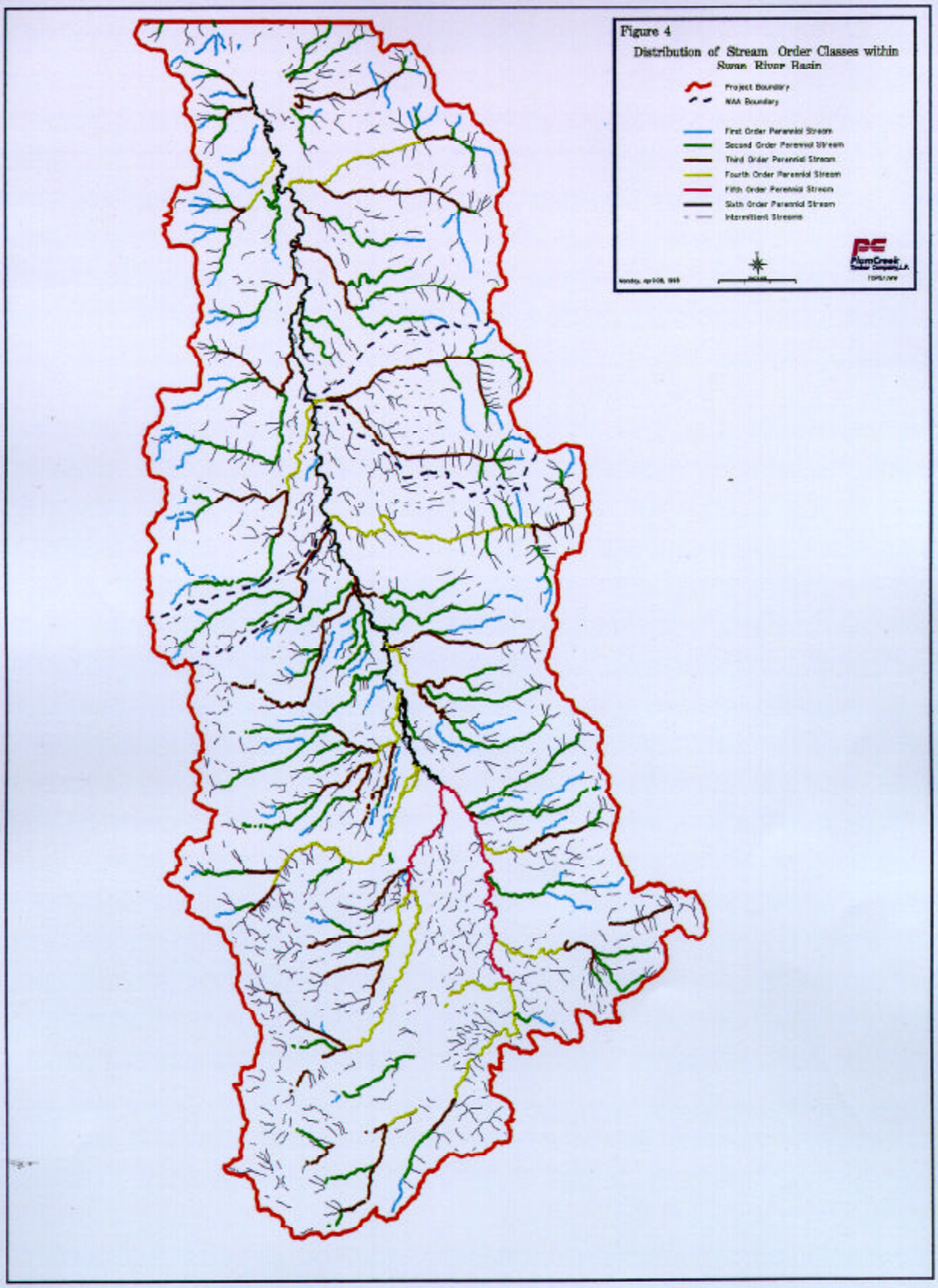


Figure 4
Distribution of Stream Order Classes within
Swan River Basin
Project Boundary
NAA Boundary
First Order Perennial Stream
Second Order Perennial Stream
Third Order Perennial Stream
Fourth Order Perennial Stream
Fifth Order Perennial Stream
Sixth Order Perennial Stream
Intermittent Streams
PlumCreek
Timber Company, L.P.

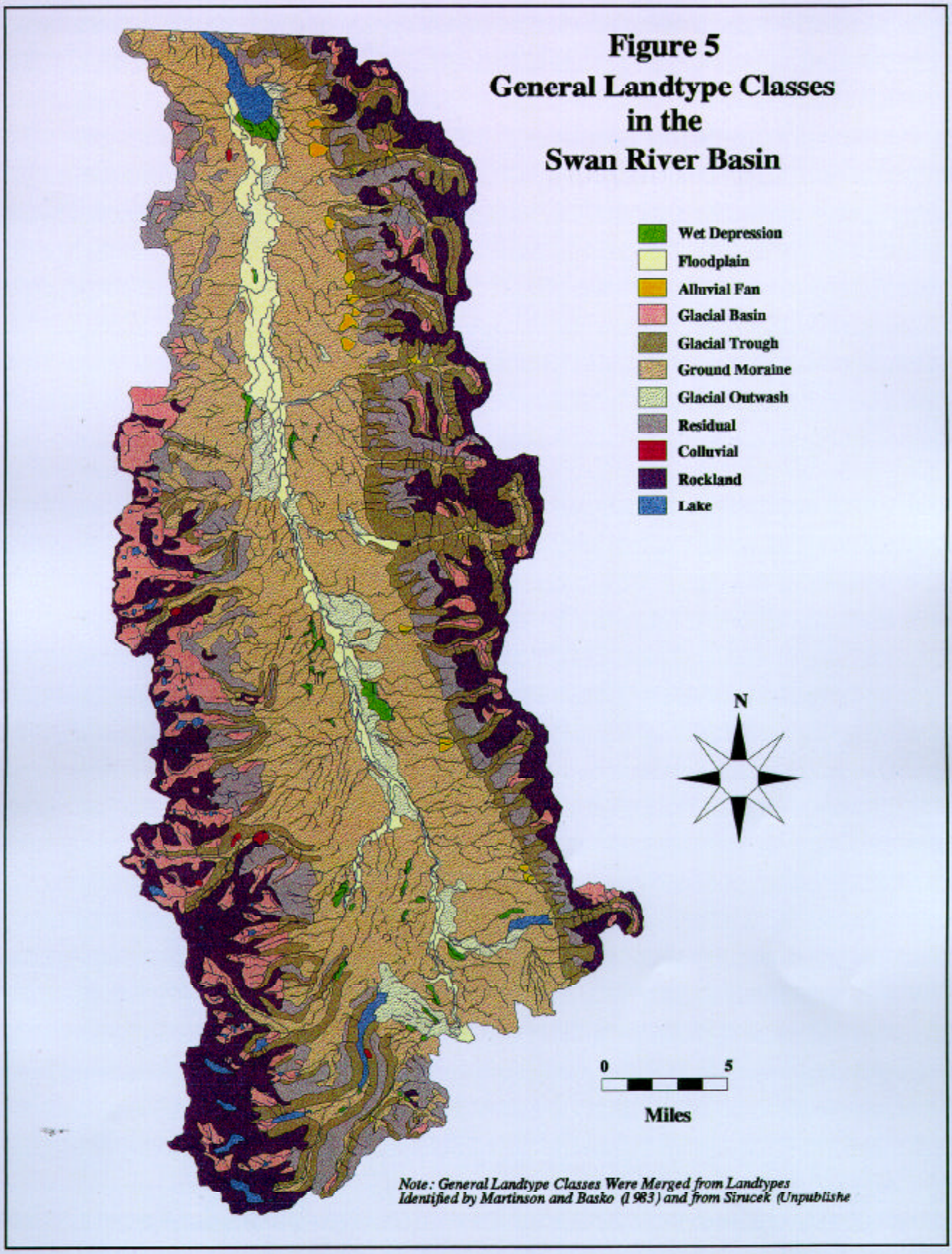


Figure 5
General Landtype Classes in the Swan River Basin

Note: General Landtype Classes Were Merged from Landtypes Identified by Martinson and Basko (1983) and from Sirucek (Unpublishe

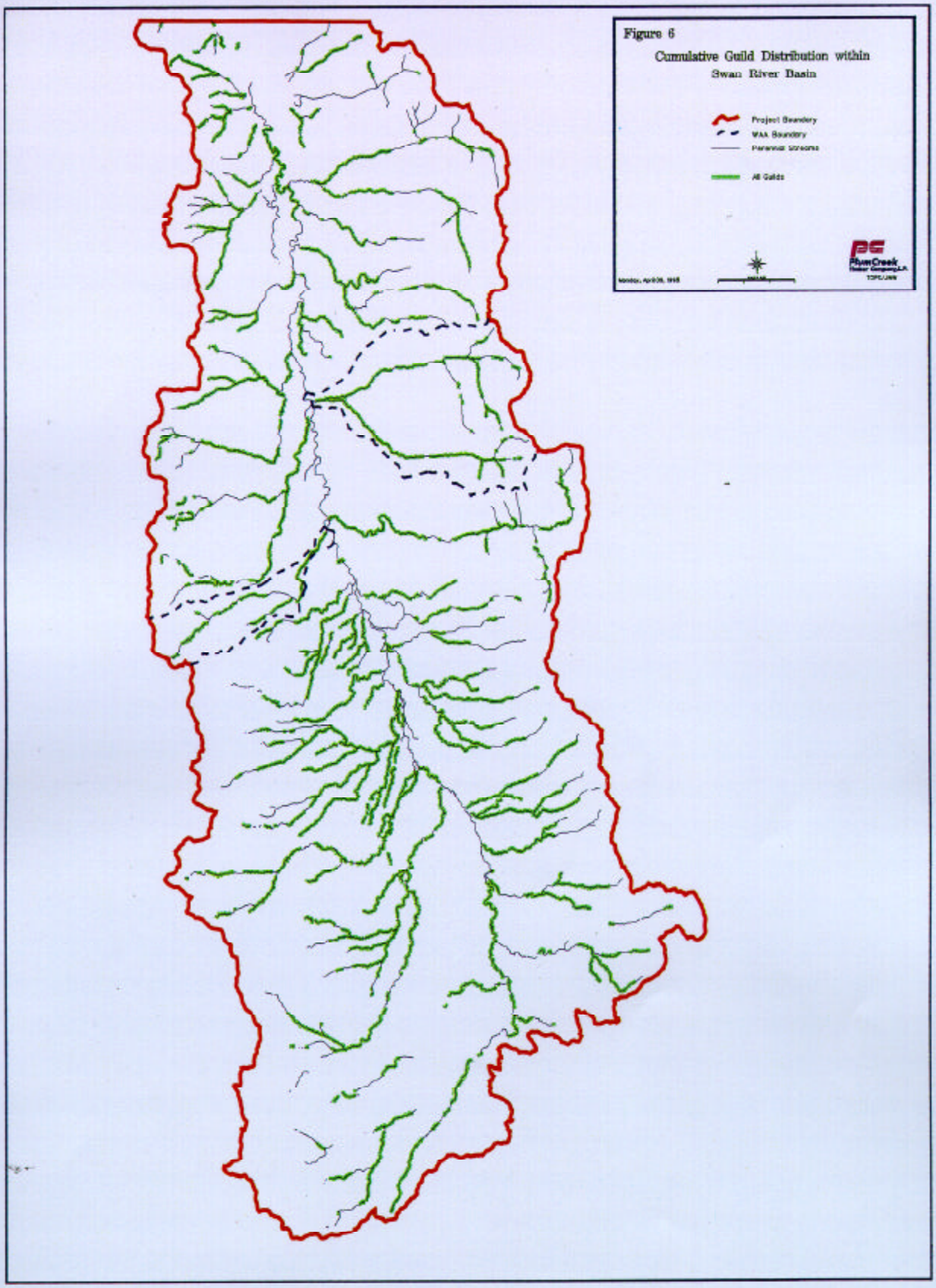


Figure 6
Cumulative Guild Distribution within
Swan River Basin
Project Boundary
WAA Boundary
Perennial streams
All Guilds

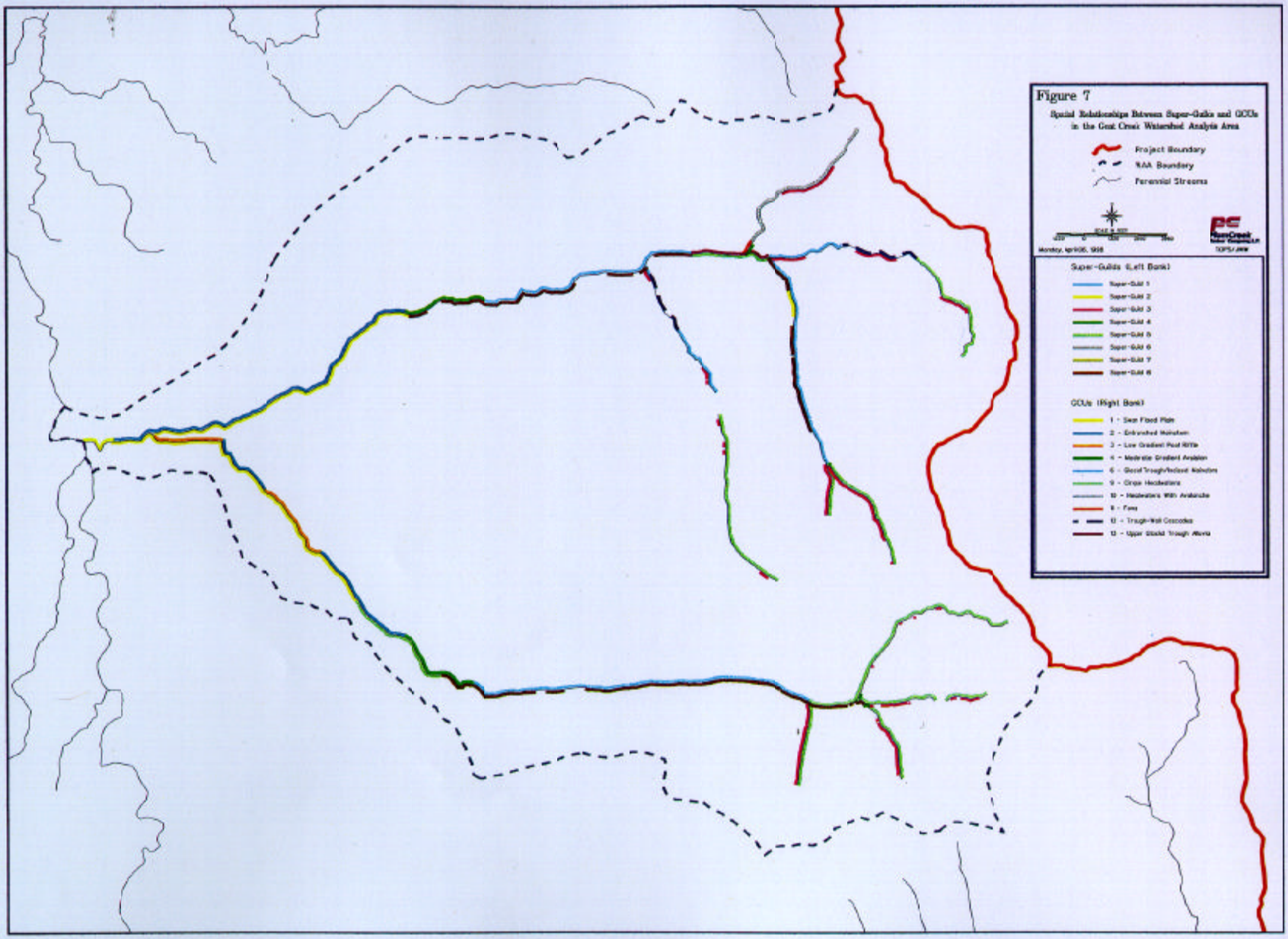


Figure 7
Spatial Relationships Between Super-Guilds and GCUs
in the Goat Creek Watershed Analysis Area
Project Boundary
WAA Boundary
Perennial Streams
Super-Guilds (Left Bank)
Super-Guild 1
Super-Guild 2
Super-Guild 3
Super-Guild 4
Super-Guild 5
Super-Guild 6
Super-Guild 7
Super-Guild 8
GCUs (Right Bank)
1 - Deep Flood Plain
2 - Entrenched Meandern
3 - Low Gradient Pool Riffle
4 - Moderate Gradient Anabran
6 - Good Trough/Incised Meandern
9 - Cirque Headwaters
10 - Headwaters With Avalanche
11 - Fans
12 - Trough-Wall Cascades
13 - Upper Glacial Trough Alluvia

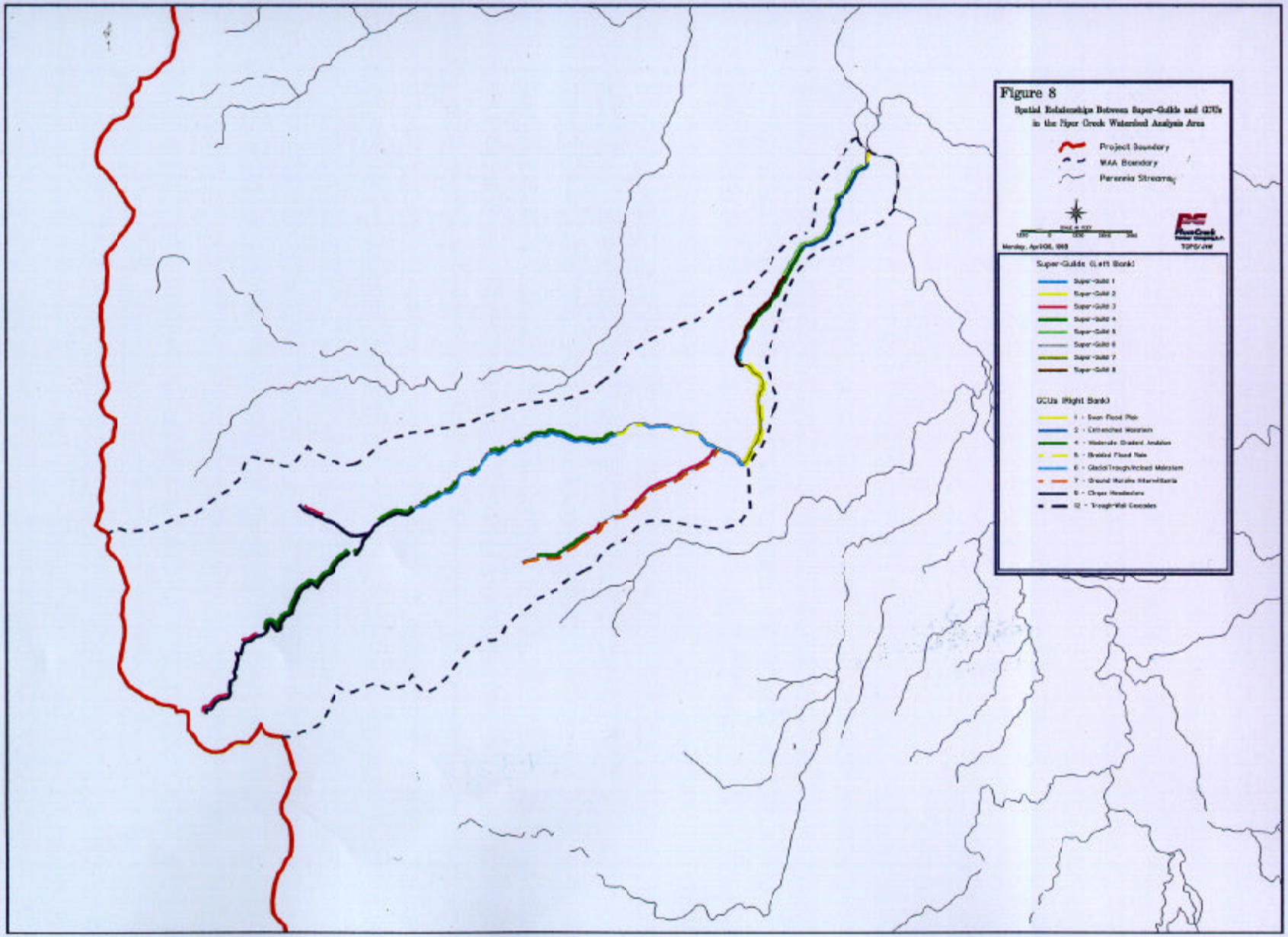


Figure 8

Spatial Relationships Between Super-Guilds and GCUs in the Piper Creek Watershed Analysis Area

Swan River Basin

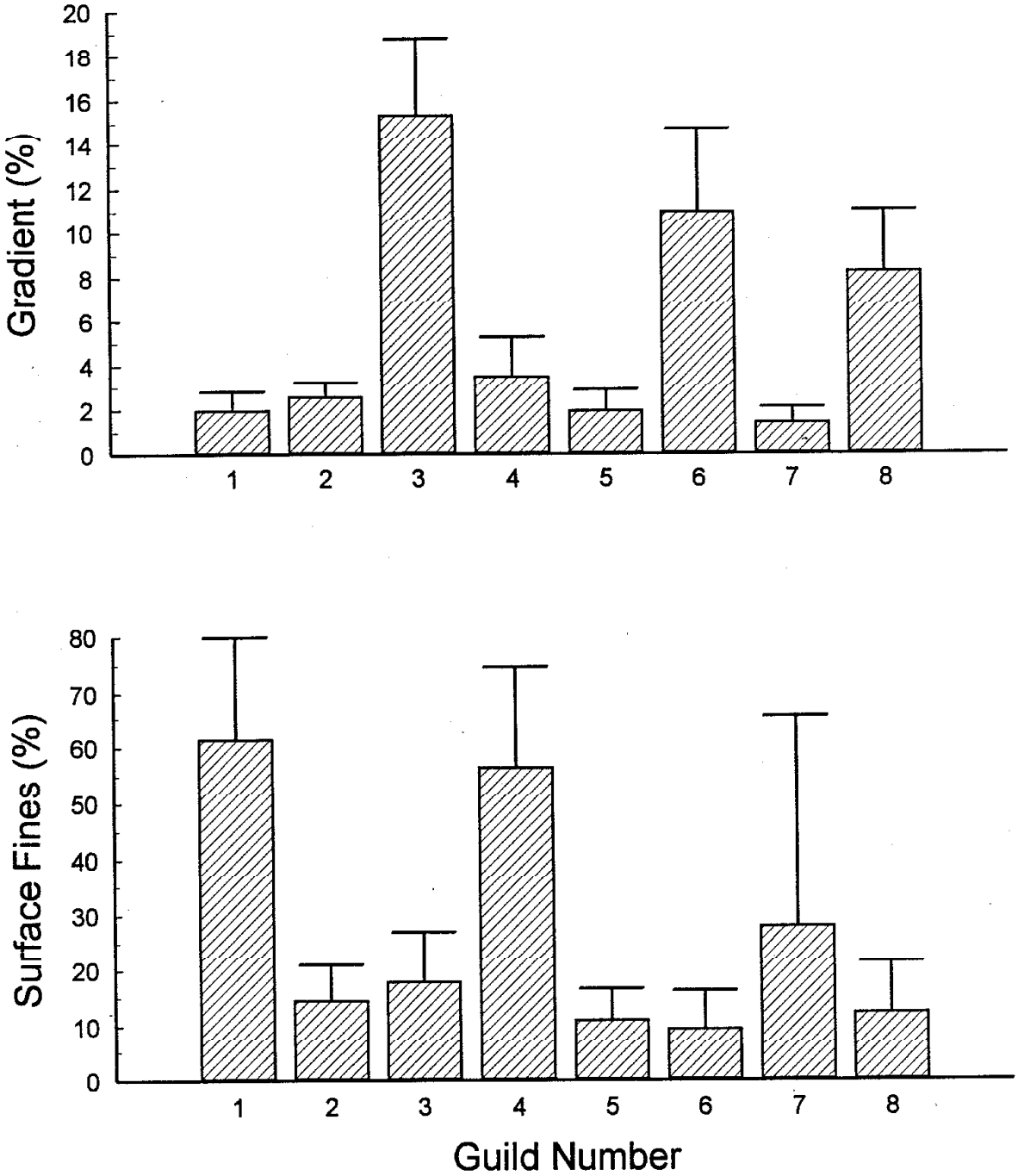


Figure 9a. Mean and 95% CI of stream gradients and percent surface fines among eight super-guild types in the Swan River Basin, Montana. Guild types are described in Table 11.

Swan River Basin

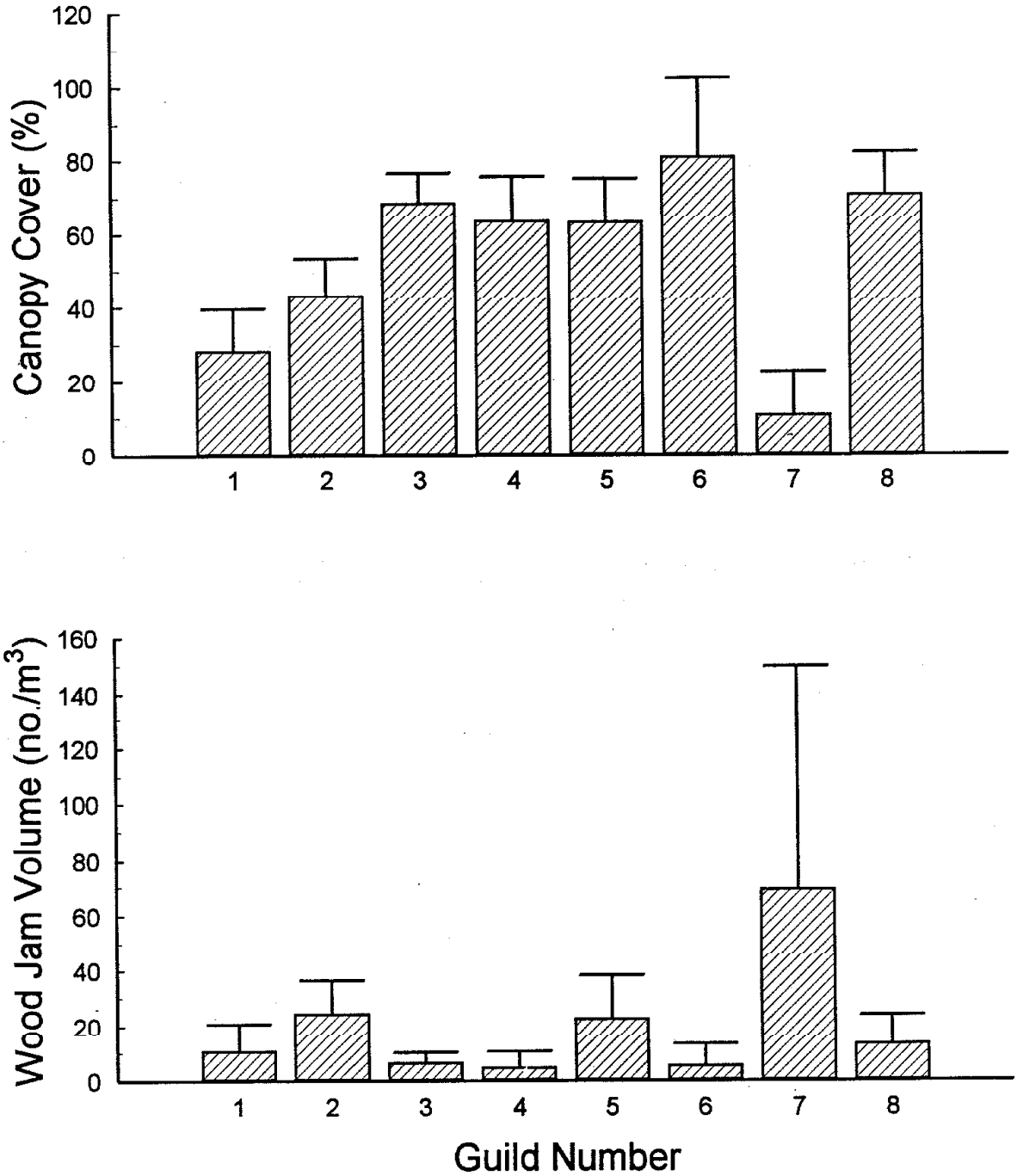


Figure 9b. Mean and 95% CI of percent canopy cover and wood jam volume among eight super-guild types in the Swan River, Montana. Guild types are described in Table 11.

Swan River Basin

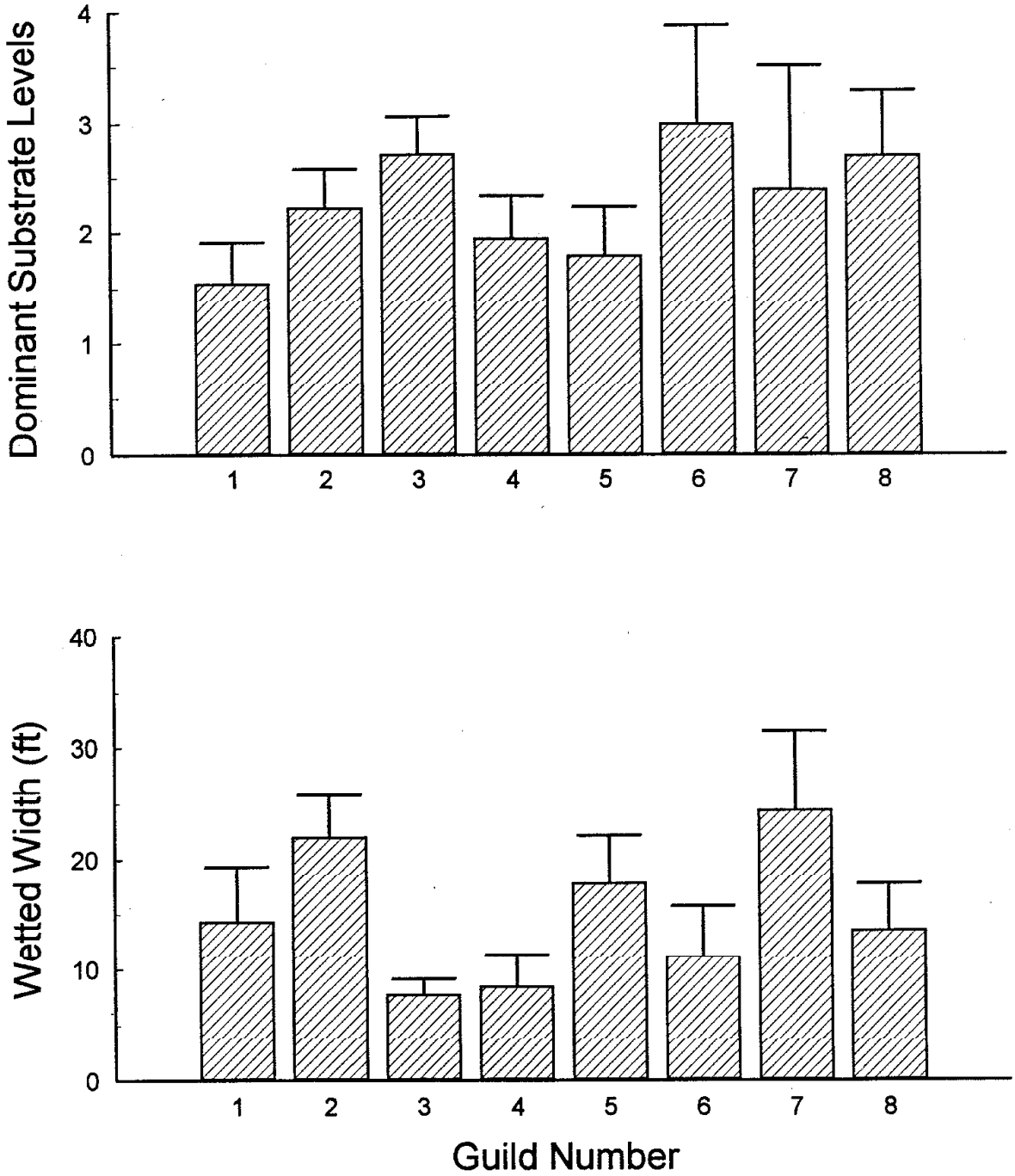


Figure 9c. Mean and 95% CI of dominant substrate levels and wetted widths among eight super-guild types in the Swan River Basin, Montana. Guild types are described in Table 11.

Swan River Basin

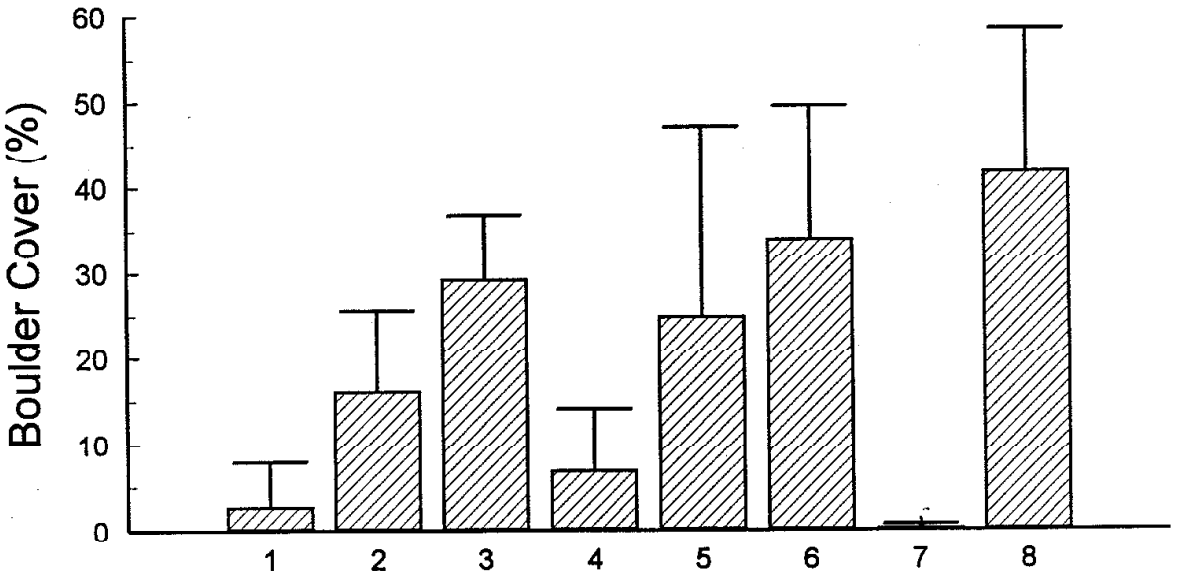


Figure 9d. Mean and 95% CI of percent boulder cover and non-pool depths among eight super-guild types in the Swan River Basin, Montana. Guild types are described in Table 11.

Swan River Basin

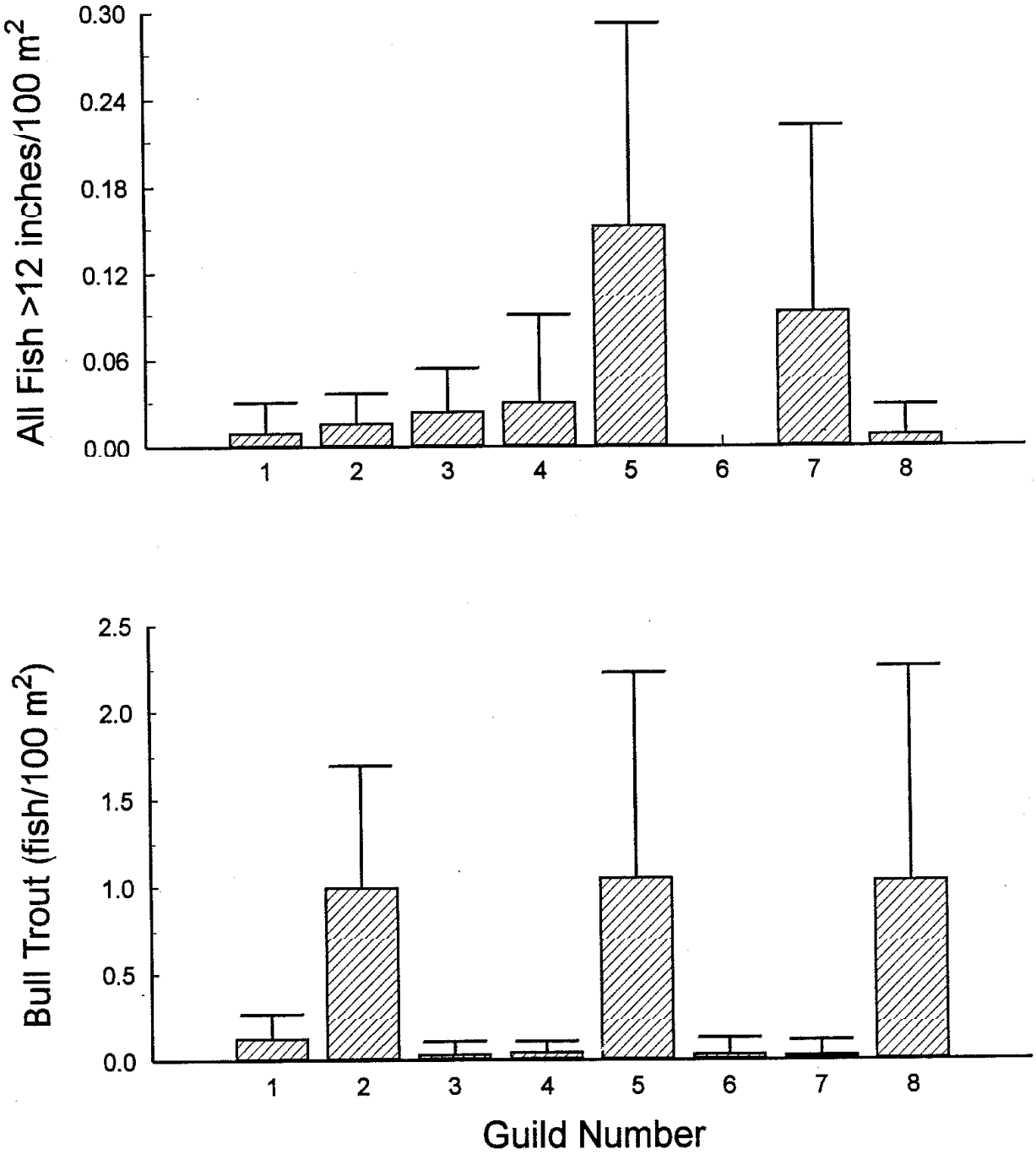
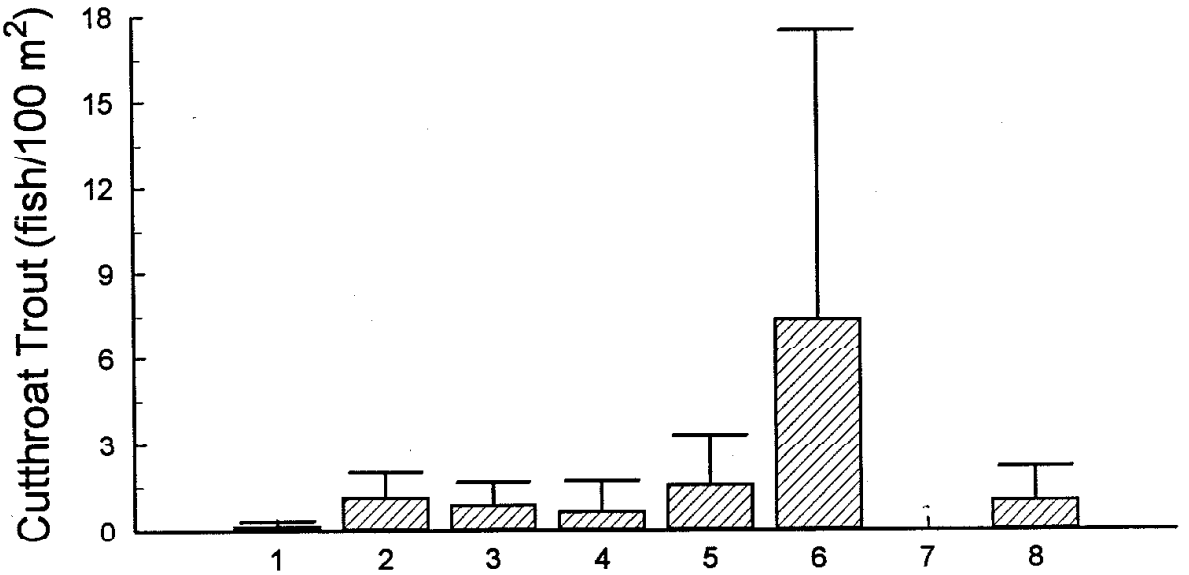


Figure 9e. Mean and 95% CI of fish larger than 12 inches and bull trout among eight super-guild tyes in the Swan River Basin, Montana. Guild types are described in Table 11.

Swan River Basin



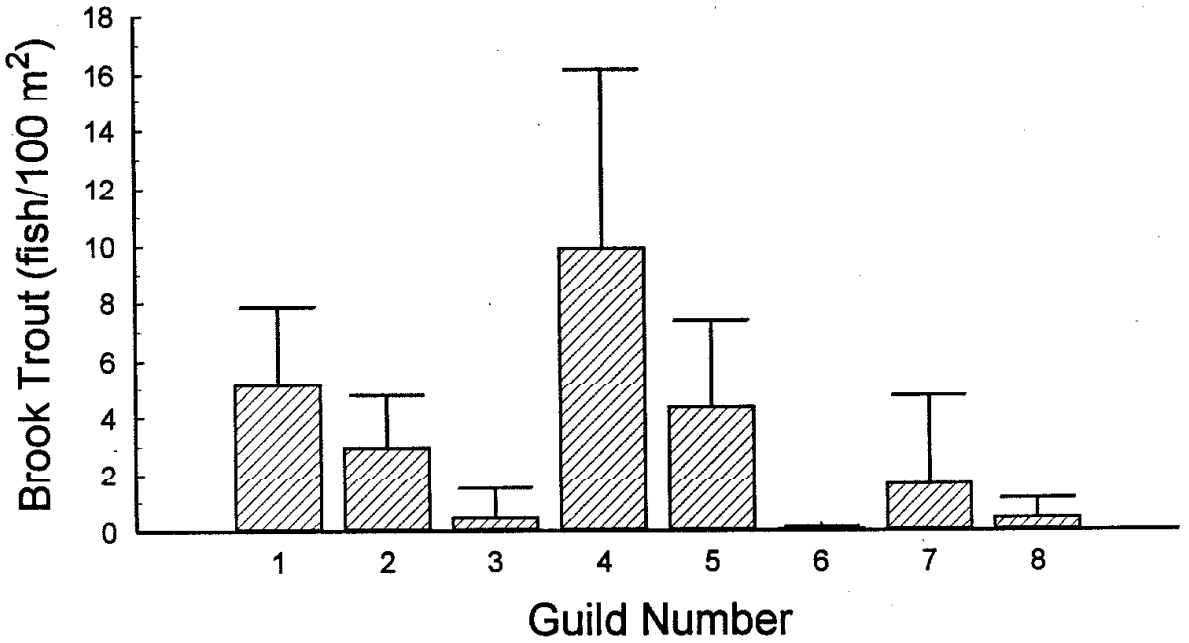
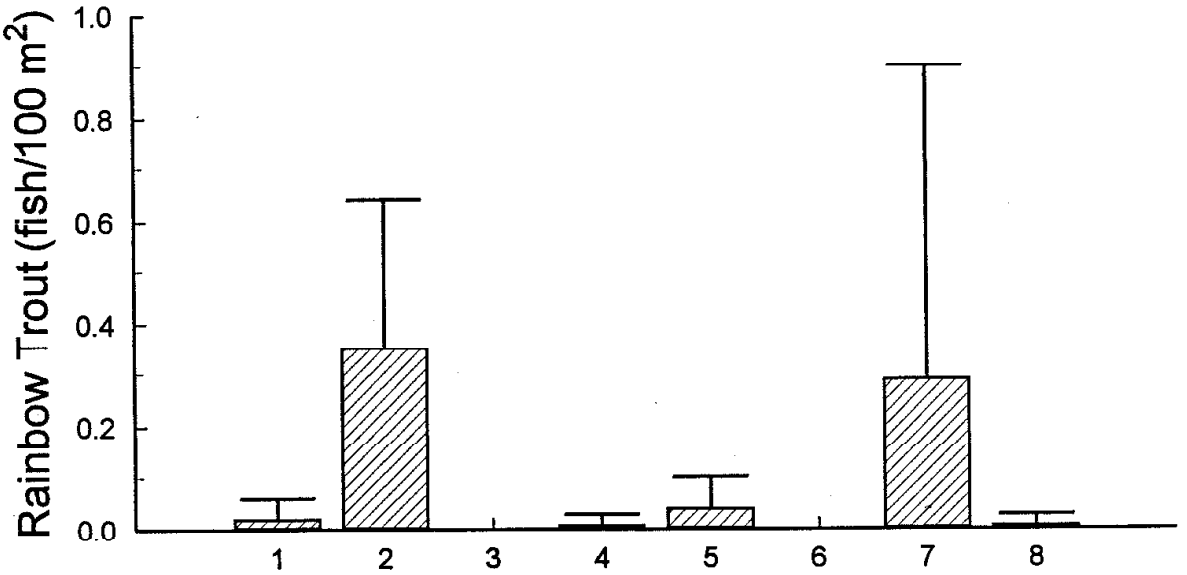


Figure 9f. Mean and 95% CI of cutthroat trout and brook trout densities among eight super-guild types in the Swna River Basin, Montana. Guild types are described in Table 11.

Swan River Basin



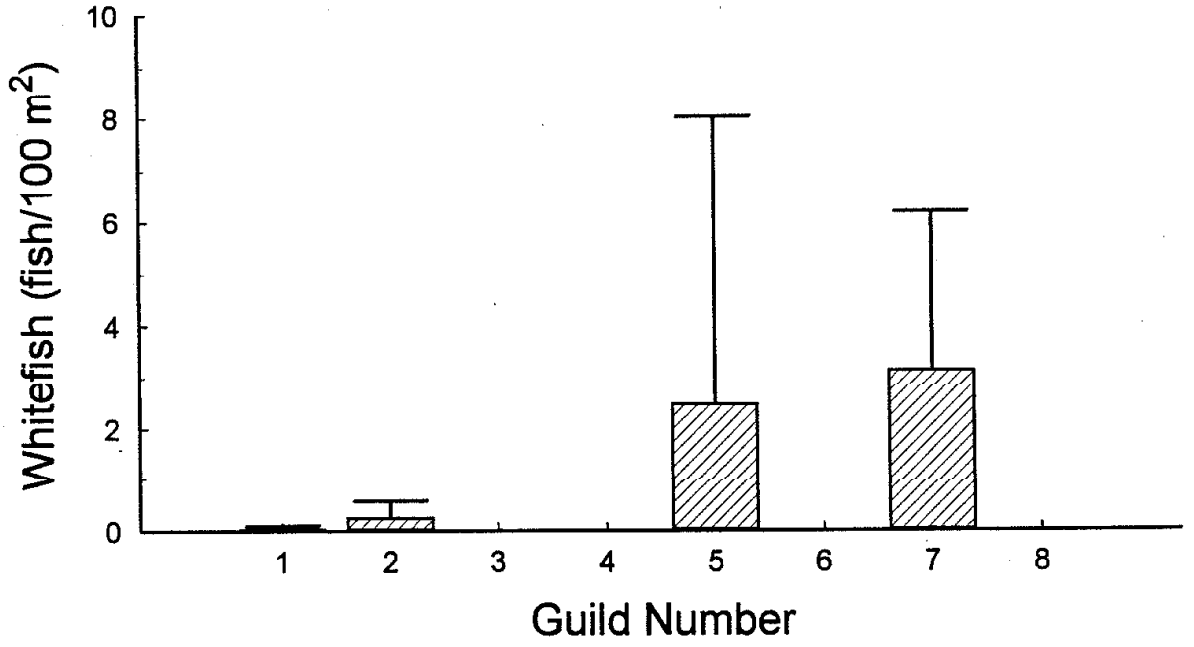


Figure 9g. Mean and 95% CI of rainbow trout and mountain whitefish densities among eight super-guild types in the Swna River Basin, Montana. Guild types are described in Table 11.

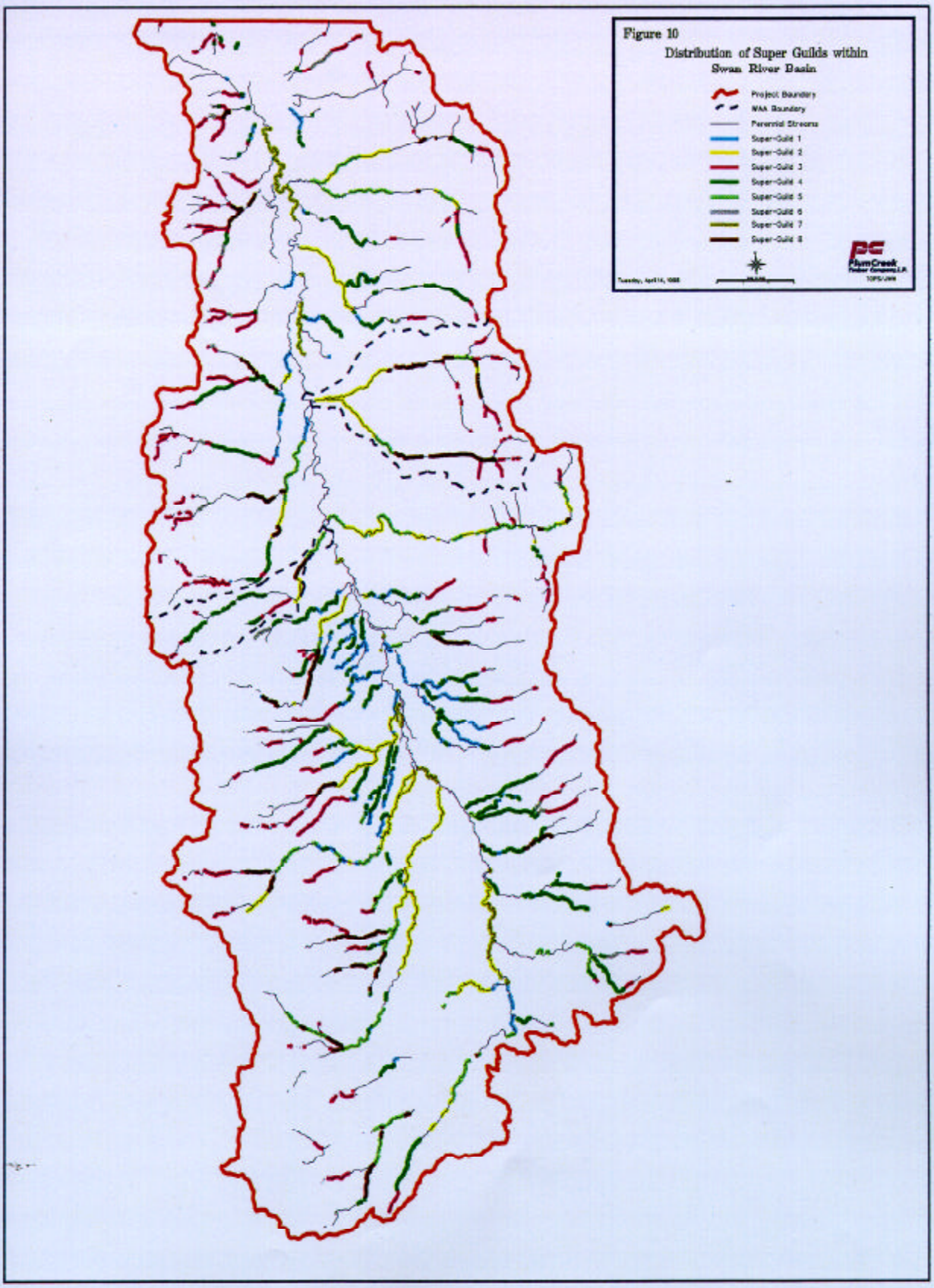
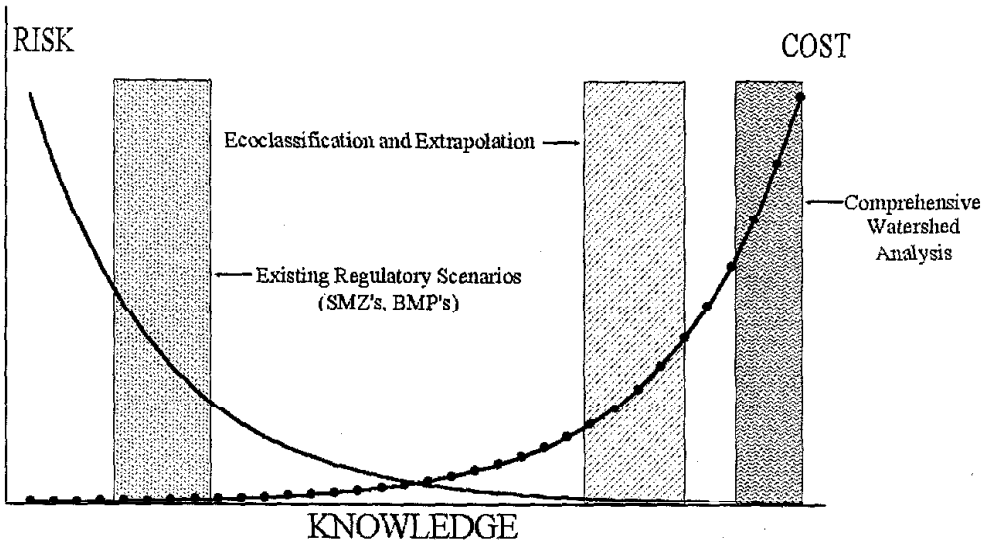


Figure 10
Distribution of Super Guilds within
Swan River Basin
Project Boundary
WAA Boundary
Perennial Streams
Super-Guild 1
Super-Guild 2
Super-Guild 3
Super-Guild 4
Super-Guild 5
Super-Guild 6
Super-Guild 7
Super-Guild 8
PlumCreek

Figure 11. Conceptual Representation of Cost/Benefits Paradigm for Natural Resources Management



Glossary

ANOVA (Analysis of Variance)--This test is a form of statistical analysis useful for assessing the statistical significance of differences among two or more means simultaneously. It does so by comparing the relative variation between groups to the variation within groups.

Cell--This term, as used in section 2. Process Description, depicts the individual elements of the synthesis process (Figure 1b). For each "cell" in the process, data/information is analyzed/interpreted to generate results used in subsequent "cells".

CMZ (Channel Migration Zone)--This term is used in watershed analysis and refers to stream reaches where bank erosion, or formation and/or occupancy of side channels is markedly more frequent than in other reaches. It has been developed to acknowledge that streams and rivers change position on their floodplains, and that valley bottom forest stands remote from the channel could become riparian stands adjacent to channels over a period as short as years to decades.

Channel Sensitivity (of a particular channel class)--The degree to which management activity affecting a specified range of watershed processes (e.g. surface erosion) is expected to potentially change specific physical aspects of channel morphology (e.g. fine sediment deposits in the channel).

Channel Vulnerability (of a particular channel class)--The degree to which management activity affecting a specified range of watershed processes (e.g. surface erosion) is expected to potentially change specific biological aspects of aquatic habitat (e.g. fine sediment deposits in the channel); vulnerability should be thought of as the biotic counterpart of channel sensitivity. The degree of channel sensitivity and vulnerability are not always in agreement.

Coefficient of Variation--This is a measure of dispersion for interval-level data.

Confinement Classes--This term is used in watershed analysis to characterize the relationship between stream channels, floodplains and hillslopes. Confined streams have a narrow floodplain, typically because valley walls are near the stream on both sides and allow little space for the channel to move or spread laterally. Unconfined streams have broad floodplains, and moderately confined streams have modest floodplains. The Washington Watershed Analysis criteria compare valley width to bankfull channel width in a ratio. When the ratio is < 2, the channel is said to be confined; when it is > 4, it is said to be unconfined, with intermediate values indicating moderate confinement.

Covariance--This is the first product moment of two variables about their mean values. Two variables covary when as the values of one change, so do the values of the other.

Dependent Variable--A dependent variable is one which is influenced or caused by some other

variable. The dependent variable is sometimes called the criterion variable.

Effect Size--This refers to the size of an "effect" to be detected by some statistical analysis. An effect might be the difference between two means or the size of a correlation coefficient. Effect size must often be estimated to predict the sample size needed for an analysis.

Error Mean-Square--This is the error sum of squares divided by its number of degrees of freedom.

Error Sum of Squares--In ANOVA, the residuals left after extracting the variance explained by various main effects and interactions represent error and the sum of squares of these residuals is called the error sum of squares. This could also be called "residual sum of squares."

F Test The F test is a statistical test of significance based on ANOVA, which is often used in tests of significance for particular statistics such as measures of association.

GCU (Geomorphic Channel Unit)--Equivalent to geomorphic map unit (GMU) as stated in Washington Watershed Analysis guidance manuals. The term refers to stream channel segments or reaches that have been grouped together as a single channel class, reflecting similarities in form, structural processes, and sensitivity to potential management effects.

Geomorphic Guild--A group of channel segments in the study area expected to exhibit similar characteristics in terms of fish populations, fish habitat, form, structural processes, and sensitivity to potential management effects. Individual geomorphic guilds were identified, through the hierarchical ecoclassification process, as a group of channel segments having the same riparian landtype (RLT), stream order class, and landtype class (LTC).

Hazards--This term is used in watershed analysis and refers to circumstances where stream habitat may be impaired by forest management activities, such as road construction using sidecast construction techniques on steep slopes near streams, which creates the potential for mass wasting that delivers sediment to streams that could degrade spawning or rearing habitat.

Independent Samples--These samples are non-overlapping samples of cases. That is, cases in one sample will not be included in the other sample.

Independent Variable--An independent variable is one which is thought to cause another dependent variable, but which is not itself caused by any of the variables in the analysis.

Inputs--This term is used in watershed analysis and refers to watershed contributions to streams in the form of eroded sediment (coarse or fine), LWD recruited from riparian zones or by landslides, runoff from rainfall and snowmelt, and heat from solar radiation as influenced by riparian zone vegetation.

K-Means Clustering--K-means cluster analysis is a method of cluster analysis for very large data sets in which k points are identified in space and items merged with them one at a time until

all items are placed in the k clusters.

Kruskal-Wallis Test--This nonparametric test evaluates the null hypothesis that k independent groups have equal centers or medians. It assumes the underlying distribution is continuous. When there are only two groups, it is equivalent to the Mann-Whitney U test.

Landform -- a feature of the earth's surface that is distinguished from adjacent features by morphology, position relative to environmental gradients, and mode of genesis. Examples of landforms are lateral moraine, alluvial fan, lake terrace, foot slope, stream channel, etc. Landforms generally correspond with relatively specific soil types. They are typically mapped at scales larger than 1:24,000.

Landtype -- commonly an assemblage of two or more landforms that recur in predictable patterns and that are generally managed as an entity. Landtypes are typically mapped at 1:24,000 to 1:60,000 scale and are a level of the Land Systems Inventory (Wertz and Arnold 1972).

Median--The median is a measure of central tendency that divides a distribution into half so that 50% of the cases have higher values than the median and 50% have lower values.

Meta-Ecoterra Zone--The hypothetical geographic area that delineates the extent of reliable extrapolation of the vulnerabilities and hazards described by this study. This as yet designated area is likely to be defined at some mid-level in the hierarchical classification. Hence, the meta-ecoterra zone will be at least as large as the river basin, but smaller than the subject ecoregion.

Mode--The mode is the value or category of a variable occurring most frequently. In other words, it is the category having the greatest frequency of cases.

Multicollinearity--This is a condition in which there are high correlations among independent variables. Multicollinearity makes it difficult for computational procedures to estimate parameters, leading to unstable estimates of regression coefficients and high standard errors of those estimates.

Multiple Discriminant Analysis--This is a technique for finding the linear additive combination of independent variables that best classifies cases into separate categories of some nominal-level categorical dependent variable. It can be used when there are two or more categories of the dependent variable.

Newman-Keuls Test--This test is a multiple comparison test using the studentized ranges rather than mean values.

Pearson Correlation--The Pearson product-moment correlation coefficient provides a symmetric measure of association between two variables. It assumes a linear relationship between the two variables.

Power--The power of a test is a measure of its ability to detect small differences. The larger the

power, the more it is able to detect such differences. Typically, more powerful tests use more of the information available in data and less powerful tests often discard or ignore important information. More powerful test can detect smaller effects for a given sample size or can detect effects of a given size using smaller samples than less powerful tests. Statistical power is defined as 1 minus the probability of incorrectly concluding there is no difference between groups. Power, then, is the probability of correctly concluding there is a significant difference among groups

Power Analysis--Power analysis is a method often used to determine the appropriate sample size for an empirical study. If the researchers can specify the expected effect size, the alpha level desired for a statistical test, the statistic, the desired level of power, and an estimate of the variation in the data, then that information can be used to compute the sample size required to conclude that an effect of a given size is statistically significant.

Species Richness--The absolute number of species in an assemblage or community.

Standard Error--The standard error is the standard deviation of a sampling distribution of means. The standard error is larger if there is more variation in a population parameter. However, the standard error is decreased as sample size increases. Standard error is often used in power analysis to determine appropriate sample size.

Super GCU--Classification of channels according to geomorphic characteristics can be done at different spatial scales, reflecting different purposes or different emphasis on geomorphic factors. Super GCU's in this paper are groups or clusters of GCU's with common landscape characteristics and similar, but not identical, form, structural processes and sensitivity.

Super Guilds--These are groups of geomorphic guilds expected to exhibit similar fish populations, fish habitat, form, structural processes and vulnerability to land management effects. Super guilds were determined by combining the results of cluster analysis (K-means clustering of geomorphic guilds using biological and physical parameters) with the results of watershed analysis (identification of spatially corresponding GCU's and super GCU's). Super guilds are the basis for extrapolation of channel vulnerabilities throughout the river basin.

Triggering Mechanisms--This term is used in watershed analysis and refers to both natural processes and management activities that cause an event that may potentially affect streams. For example, sidecast of road construction spoil on convergent slopes where water is concentrated during high intensity rainfall/runoff is a triggering mechanism for mass wasting.

T-Test--The T-test is a test of statistical significance used to compare two means. It relies on Student's t distribution rather than the normal distribution.

Type I Error (Alpha)--Type I error is the probability of concluding there is a significant difference when there is none. Alpha levels are set by the researcher as a standard against which to judge results of tests. Results with probabilities less than alpha (e.g., $P<0.05$) are judged to be significant. Alpha is sometimes called the significance level.

Appendix A

Descriptive Statistics of Dependent and Independent Variables

Appendix A

DESCRIPTIVE STATISTICS OF DEPENDENT VARIABLES

SUPER GUILD	STATISTICS	ALL	3	6	9	12	>12	BL	CT	BK	RB	WF
1	N of cases	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
1	Mean	5.501	2.303	2.408	0.600	0.179	0.010	0.122	0.166	5.157	0.021	0.034
1	Std. Error	1.266	0.659	0.603	0.281	0.117	0.010	0.071	0.079	1.284	0.021	0.034
1	Standard Dev	5.656	2.949	2.699	1.256	0.525	0.046	0.317	0.351	5.744	0.095	0.154
2	N of cases	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000
2	Mean	5.755	2.328	2.501	0.703	0.207	0.016	0.997	1.166	2.977	0.352	0.264
2	Std. Error	0.964	0.600	0.447	0.140	0.047	0.008	0.340	0.406	0.872	0.143	0.157
2	Standard Dev	4.818	2.998	2.236	0.699	0.236	0.042	1.699	2.031	4.361	0.716	0.784
3	N of cases	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000
3	Mean	1.425	0.125	1.054	0.204	0.018	0.024	0.034	0.897	0.493	0.000	0.000
3	Std. Error	0.601	0.078	0.505	0.074	0.014	0.017	0.034	0.381	0.493	0.000	0.000
3	Standard Dev	3.554	0.459	2.990	0.437	0.082	0.099	0.203	2.254	2.919	0.000	0.000
4	N of cases	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
4	Mean	10.642	5.905	4.077	0.581	0.050	0.030	0.045	0.676	9.912	0.009	0.000
4	Std. Error	2.935	1.888	1.219	0.202	0.032	0.030	0.031	0.493	2.982	0.009	0.000
4	Standard Dev	13.126	8.446	5.450	0.902	0.144	0.133	0.137	2.203	13.336	0.039	0.000
5	N of cases	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
5	Mean	9.452	4.364	3.364	1.254	0.328	0.152	1.052	1.580	4.346	0.041	2.482
5	Std. Error	2.881	2.266	0.670	0.192	0.127	0.063	0.521	0.766	1.329	0.028	2.455
5	Standard Dev	9.046	7.133	2.118	0.606	0.402	0.199	1.647	2.422	4.203	0.088	7.764
6	N of cases	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
6	Mean	7.459	1.195	4.084	1.931	0.259	0.000	0.034	7.401	0.034	0.000	0.000
6	Std. Error	3.596	0.608	1.956	1.237	0.177	0.000	0.034	3.626	0.034	0.000	0.000
6	Standard Dev	8.040	1.359	4.374	2.767	0.396	0.000	0.076	8.108	0.076	0.000	0.000
7	N of cases	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000
7	Mean	5.118	0.748	3.799	0.219	0.260	0.092	0.030	0.000	1.643	0.290	3.155
7	Std. Error	1.773	0.355	1.474	0.065	0.135	0.047	0.030	0.000	1.113	0.218	1.091
7	Standard Dev	3.965	0.794	3.296	0.146	0.302	0.104	0.067	0.000	2.488	0.488	2.440
8	N of cases	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
8	Mean	2.525	0.429	1.440	0.560	0.088	0.008	1.033	1.028	0.465	0.008	0.000
8	Std. Error	0.710	0.207	0.468	0.138	0.037	0.008	0.544	0.509	0.285	0.008	0.000
8	Standard Dev	2.246	0.656	1.479	0.437	0.118	0.027	1.719	1.611	0.901	0.027	0.000

Appendix A

DESCRIPTIVE STATISTICS OF INDEPENDENT VARIABLES

SUPER GUILD	STATISTICS	BFW	BFD	GRAD	PPLAR	MNWW	NPLMDP	XDPRPD	XDPRWIW	LVLSDS	MODEDSB	MODEMB	XPERWD	XPWPF	XPBLDR	XPSF	XPUC
1	N of cases	20.000	20.000	20.000	20.000	20.000	20.000	15.000	12.000	20.000	20.000	20.000	20000	15.000	20.000	20.000	20.000
1	Mean	17.420	31.050	1.975	23.830	14.380	22.385	22.107	22.200	1.550	4.750	1.000	9900	8.111	2.780	61.430	42.765
1	Std. Error	3.255	2.879	0.401	4.811	2.371	1.981	2.474	2.991	0.170	0.307	0.290	2272	1.164	2.459	8.818	4.896
1	Standard Dev	14.555	12.874	1.795	21.517	10.602	8.857	9.583	10.362	0.759	1.372	1.298	10161	6.057	10.996	39.433	21.7[illegible]9
2	N of cases	25.000	25.000	25.000	25.000	25.000	25.000	25.000	24.000	25.000	25.000	21.000	25000	25.000	25.000	25.000	25.000
2	Mean	33.060	38.000	2.600	36.652	22.040	18.548	22.560	21.900	2.240	3.200	1.280	10088	11.309	18.144	14.650	33.548
2	Std. Error	2.760	2.179	0.321	5.038	1.812	1.368	1.523	1.531	0.166	0.163	0.235	1757	2.149	4.586	3.057	3.311
2	Standard Dev	13.802	10.893	1.607	25.191	9.060	6.838	7.615	7.500	0.831	0.816	1.173	8787	10.746	22.529	15.285	16.953
3	N of cases	35.000	35.000	35.000	35.000	35.000	35.000	33.000	33.000	35.000	35.000	31.000	35000	33.000	35.000	35.000	35.000
3	Mean	13.360	24.543	15.343	28.177	7.786	10.640	13.485	13.830	2.714	2.886	1.514	9120	7.329	29.237	17.989	29.416
3	Std. Error	1.240	1.483	1.688	2.665	0.673	1.011	1.133	1.310	0.172	0.224	0.240	0883	0.760	3.721	4.483	4.476
3	Standard Dev	7.335	8.776	9.988	15.766	3.980	5.981	6.509	7.527	1.017	1.323	1.422	5226	4.366	22.015	26.519	26.478
4	N of cases	20.000	20.000	20.000	20.000	20.000	20.000	17.000	15.000	20.000	20.000	20.000	20000	17.000	20.000	20.000	20.000
4	Mean	13.500	25.350	3.500	24.995	8.500	12.285	11.618	11.080	1.950	4.800	2.100	11505	10.300	6.920	56.475	38.985
4	Std. Error	2.836	2.461	0.851	4.695	1.402	1.765	1.223	1.221	0.185	0.287	0.298	2412	2.321	3.418	8.685	6.114
4	Standard Dev	12.684	11.004	3.804	20.997	6.271	7.892	5.044	4.729	0.826	1.281	1.334	10788	11.331	15.287	38.841	27.655
5	N of cases	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10000	10.000	10.000	10.000	10.000
5	Mean	25.600	33.300	1.950	33.920	17.810	17.110	21.120	20.670	1.800	3.000	4.000	9330	10.079	24.520	11.200	31.370
5	Std. Error	1.572	2.512	0.411	6.159	1.906	2.229	2.018	2.091	0.200	0.211	0.211	2125	2.183	9.789	2.427	5.112
5	Standard Dev	4.971	7.945	1.301	19.476	6.028	7.048	6.382	6.613	0.632	0.667	0.667	6719	7.352	30.956	7.674	16.218
6	N of cases	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5000	5.000	5.000	5.000	5.000
6	Mean	17.860	29.800	11.000	30.820	11.260	18.160	13.160	13.320	3.000	2.600	3.200	8040	9.908	34.060	9.580	28.340
6	Std. Error	2.379	2.939	1.342	5.754	1.613	3.623	1.075	0.978	0.316	0.246	0.200	2412	2.120	5.546	2.409	10.913
6	Standard Dev	5.320	6.573	3.000	12.867	3.607	8.101	2.405	2.188	0.707	0.548	0.447	5393	5.158	12.407	5.386	24.417
7	N of cases	5.000	5.000	5.000	5.000	5.000	5.000	4.000	4.000	5.000	5.000	5.000	5000	4.000	5.000	5.000	5.000
7	Mean	45.600	36.000	1.400	17.400	24.400	23.040	22.500	21.525	2.400	3.000	3.600	8180	17.709	0.240	28.140	33.510
7	Std. Error	[illegible]	[illegible]	0.245	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.400	0.000	0.245	2443	3.126	0.160	13.339	8.543
7	Standard Dev	11.971	8.050	0.548	15.564	5.630	[illegible]	[illegible]	4.598	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	N of cases	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10000	10.000	10.000	10.000	10.000
8	Mean	18.295	27.100	8.300	39.420	13.640	12.880	16.260	16.410	2.700	2.700	3.900	10650	12.433	41.700	12.410	44.840
8	Std. Error	2.516	1.251	1.221	4.928	1.793	1.634	1.694	1.796	0.260	0.335	0.348	2231	2.499	7.378	3.986	8.114
8	Standard Dev	7.956	3.957	3.860	15.582	5.670	4.851	5.358	5.680	0.823	1.059	1.101	7056	8.134	23.332	12.603	25.9[illegible]1

Appendix A

DESCRIPTIVE STATISTICS OF INDEPENDENT VARIABLES (Continued)

SUPER GUILD	XPVO	XPCN	HUCW	TOTCW	TNFWCW	CWPJ	RTOTFXN	XVOLALL	XVFW	XJV	TEMP	THEAR	TPLAR	CVNFD	CVRPD	XCMZ	CVCMZ
1	20.000	20.000	20.000	20.000	20.000	11.000	18.000	20.000	18.000	20.000	13.000	10.000	20.000	16.000	13.000	20.000	20.000
1	23.550	28.315	0.271	1.984	1.942	10.399	96.437	0.294	0.328	10.812	10.462	9817.230	2974.885	21.269	25.062	88.188	50.229
1	5.140	5.415	0.050	0.691	0.694	2.769	3.468	0.059	0.061	4.879	0.595	2370.817	780.320	3.241	2.828	9.391	7.364
1	22.918	24.237	0.224	2.643	2.656	9.185	14.714	0.265	0.260	21.821	2.145	10602.616	3634.417	12.966	10.198	44.383	33.023
2	25.000	25.000	25.000	25.000	25.000	24.000	25.000	25.000	25.000	25.000	25.000	15.000	25.000	21.000	21.000	25.000	25.000
2	8.240	43.533	0.513	4.182	4.153	6.321	98.620	0.547	0.547	24.578	11.180	20531.076	5172.016	24.776	32.329	70.310	74.692
2	1.314	4.791	0.036	0.568	0.571	1.326	0.556	0.084	0.065	5.758	0.592	3862.918	874.430	1.722	3.646	8.431	7.876
2	6.718	23.954	0.182	2.840	2.854	6.498	2.788	0.321	0.323	28.788	2.958	19264.589	4372.152	8.609	16.710	42.153	39.377
3	35.000	35.000	35.000	35.000	35.000	31.000	35.000	35.000	35.000	35.000	33.000	35.000	35.000	33.000	33.000	35.000	35.000
3	9.913	68.641	0.444	2.282	2.219	13.683	96.678	0.356	0.337	6.669	7.242	2977.483	967.423	28.570	37.736	19.136	104.337
3	1.303	3.891	0.049	0.279	0.273	5.715	1.085	0.040	0.037	1.769	0.334	356.912	161.995	1.738	2.844	3.372	7.818
3	8.013	23.044	0.290	1.849	1.814	31.819	6.419	0.236	0.221	10.465	1.917	2170.878	859.215	16.728	16.338	23.499	46.844
4	20.000	20.000	20.000	20.000	20.000	16.000	20.000	20.000	20.000	20.000	16.000	20.000	20.000	17.000	17.000	20.000	20.000
4	25.600	63.561	0.241	2.035	2.024	23.032	97.828	0.294	0.298	4.936	11.469	4373.005	939.620	24.712	42.324	88.513	67.863
4	5.415	5.685	0.033	0.426	0.428	9.847	1.132	0.067	0.066	2.663	1.024	1436.778	280.550	1.193	4.189	20.040	7.389
4	24.367	25.440	0.150	1.907	1.913	39.388	5.063	0.298	0.298	11.907	4.097	6425.468	1120.492	13.167	17.271	89.821	33.044
5	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
5	9.300	63.290	0.446	3.376	3.114	10.469	93.418	0.729	0.709	22.911	11.000	13306.550	3418.990	31.150	29.940	42.025	89.663
5	1.960	5.208	0.047	0.706	0.636	2.862	3.878	0.137	0.136	6.775	1.470	3071.707	462.763	4.047	3.848	7.505	14.732
5	6.157	16.468	0.149	2.233	2.011	9.019	12.264	0.433	0.430	21.424	4.649	9713.592	1463.385	12.798	12.170	24.049	46.887
6	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	1.000	5.000	5.000	5.000
6	8.600	80.880	0.847	3.674	3.650	3.466	99.024	0.487	0.489	5.860	10.000	5050.660	1574.800	23.760	36.420	24.350	76.387
6	0.859	7.671	0.150	1.061	1.058	0.322	0.718	0.126	0.125	2.713	1.789	1114.466	539.660	1.442	6.636	13.706	18.808
6	1.958	17.165	0.335	2.349	2.367	0.721	1.608	0.282	0.280	6.067	4.000	2511.463	1206.717	11.169	14.840	30.549	42.280
7	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	1.000	4.000	5.000	5.000
7	5.920	10.700	0.609	6.548	6.548	6.692	100.000	0.808	0.808	69.336	12.400	27817.580	4681.080	41.020	47.875	78.500	48.944
7	0.769	4.263	0.122	1.894	1.894	1.317	0.000	0.188	0.188	28.953	1.603	7614.024	2112.782	5.153	12.917	11.152	4.671
7	1.888	9.608	0.279	4.235	4.235	3.944	0.000	0.421	0.421	64.740	3.382	17047.838	4721.326	11.521	26.834	24.937	10.221
8	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	9.000	0.000	10.000	10.000	10.000	10.000	10.000
8	7.540	70.880	0.529	3.046	2.986	5.782	97.516	0.353	0.344	13.309	8.778	6416.020	2609.050	26.430	31.970	21.650	90.147
8	1.568	4.894	0.076	0.402	0.403	1.021	1.467	0.060	0.058	4.684	0.619	1242.552	630.182	3.695	4.317	5.792	12.922
8	4.958	15.475	0.241	1.270	1.275	3.229	4.639	0.190	0.185	14.812	1.856	3939.294	1992.810	11.683	13.650	18.317	40.864

Appendix B

Results of T-Tests Comparing Variables Among Disturbed and Undisturbed Sites

Appendix B

RESULTS OF T-TEST COMPARING DEPENDENT VARIABLES AMONG DISTURBED AND UNDISTURBED SITES

	ALL						_3						_6						_9					
	Undisturbed		Disturbed				Undisturbed		Disturbed				Undisturbed		Disturbed				Undisturbed		Disturbed			
Super_Guild	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value
1	7.645	5.815	4.072	5.308	1.394	0.185	3.571	3.235	1.459	2.53	1.556	0.145	2.719	2.782	2.202	2.146	0.409	0.688	1.041	1.713	0.306	0.788	1.137	2.850
2	8.806	6.863	4.319	2.715	1.785	0.112	3.659	3.822	1.701	2.40	1.330	0.214	3.950	2.829	1.819	1.867	1.992	0.077	0.993	0.867	0.567	0.585	1.260	0.236
3	1.189	2.841	1.704	4.336	-0.407	0.687	0.000	.	0.274	0.65	1.663	0.117	0.870	2.363	1.272	3.669	-0.378	0.709	0.252	0.528	0.147	0.301	0.737	0.467
4	13.333	15.844	8.840	10.708	0.790	0.443	8.029	10.797	4.167	5.90	0.926	0.355	4.501	5.479	3.729	5.668	0.308	0.761	0.758	1.128	0.436	0.690	0.750	0.467
5	11.652	12.348	7.252	4.420	0.750	0.487	5.049	10.226	3.659	2.95	0.292	0.783	4.503	2.208	2.224	1.404	1.947	0.094	1.499	0.611	1.008	0.551	1.333	0.220
6	11.511	9.937	4.774	7.258	0.823	0.508	1.397	0.707	1.061	1.83	0.287	0.795	6.118	5.725	2.728	3.872	0.733	0.555	3.548	4.285	0.853	1.331	0.862	0.533
7	2.630	3.720	6.778	3.770	-1.214	0.335	0.202	0.286	1.112	0.85	-1.713	0.200	2.226	3.148	4.848	3.57	-0.866	0.461	0.081	0.114	0.311	0.067	-2.563	0.167
8	1.402	2.166	3.275	2.141	-1.348	0.223	0.519	1.036	0.369	0.34	0.279	0.796	0.539	1.025	2.042	1.491	-1.888	0.096	0.252	0.379	0.765	0.364	-2.130	0.074

	_12						>12						BL						CI					
	Undisturbed		Disturbed				Undisturbed		Disturbed				Undisturbed		Disturbed				Undisturbed		Disturbed			
Super_Guild	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value
1	0.289	0.716	0.108	0.366	0.669	0.519	0.026	0.073	0.000	.	1.000	0.351	0.064	0.266	0.141	0.358	-0.339	0.738	0.088	0.165	0.218	0.434	-0.943	0.360
2	0.205	0.252	0.207	0.236	-0.022	0.982	0.000	.	0.024	0.04	2.027	0.060	0.232	0.433	1.358	1.654	-2.259	0.036	1.680	2.728	0.924	1.654	0.721	0.486
3	0.024	0.104	0.011	0.048	0.467	0.644	0.044	0.132	0.000	.	1.450	0.164	0.063	0.276	0.000	.	1.000	0.331	1.126	2.854	0.625	1.268	0.689	0.497
4	0.045	0.095	0.054	0.179	-0.142	0.889	0.000	.	0.054	0.17	1.000	0.347	0.069	0.197	0.000	.	1.609	0.170	1.240	3.200	0.216	0.715	0.941	0.372
5	0.397	0.296	0.260	0.514	0.515	0.624	0.204	0.177	0.101	0.22	0.805	0.445	0.790	0.736	1.313	2.322	-0.480	0.652	2.099	2.796	1.080	2.169	0.653	0.531
6	0.448	0.634	0.133	0.230	0.675	0.607	0.000	.	0.000	.	N/A	N/A	0.000	.	0.057	0.09	1.000	0.423	11.511	9.937	4.660	7.345	0.835	0.502
7	0.081	0.114	0.380	0.349	-1.374	0.277	0.040	0.057	0.126	0.12	-1.032	0.381	0.000	.	0.050	0.087	1.000	0.423	0.000	.	0.000	.	N/A	N/A
8	0.092	0.108	0.086	0.134	0.080	0.939	0.000	.	0.014	0.03	1.000	0.363	1.141	2.283	0.960	1.476	0.140	0.894	0.260	0.521	1.539	1.929	-1.542	0.174

	BK						RB						WF					
	Undisturbed		Disturbed				Undisturbed		Disturbed				Undisturbed		Disturbed			
Super_Guild	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value	Mean	SD	Mean	SD	T Value	P Value
1	7.377	5.941	3.577	5.343	1.420	0.178	0.000	.	0.035	0.12	1.000	0.339	0.086	0.244	0.000	.	1.000	0.351
2	6.100	6.499	1.507	1.697	1.968	0.087	0.650	1.152	0.211	0.35	1.056	0.323	0.144	0.378	0.320	0.921	-0.674	0.507
3	0.000	.	1.378	4.317	1.000	0.333	0.000	.	0.000	.	N/A	N/A	0.000	.	0.000	.	N/A	N/A
4	11.974	16.555	8.224	10.570	0.588	0.566	0.020	0.059	0.000	.	1.000	0.347	0.000	.	0.000	.	N/A	N/A
5	3.847	3.272	4.345	5.331	-0.357	0.732	0.048	0.108	0.034	0.07	0.251	0.809	4.964	10.965	0.000	.	1.012	0.369
6	0.000	.	0.057	0.099	1.000	0.423	0.000	.	0.000	.	N/A	N/A	0.000	.	0.000	.	N/A	N/A
7	0.121	0.172	2.557	2.918	-1.501	0.271	0.162	0.229	0.375	0.65	-0.522	0.642	2.347	3.319	3.694	2.305	-0.499	0.676
8	0.000	.	0.775	1.083	1.753	0.140	0.000	.	0.014	0.03	1.000	0.363	0.000	.	0.000	.	N/A	N/A

Appendix B

RESULTS OF T-TESTS COMPARING INDEPENDENT VARIABLES AMONG DISTURBED AND UNDISTURBED SITES

BPW

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	18.913	16.038	12	16.425	14.138	0.358	0.727
2	8	24.867	8.861	17	37.000	14.612	-2.854	0.009
3	19	15.347	7.868	16	11.000	6.011	1.847	0.074
4	9	18.867	14.133	11	10.909	11.379	0.988	0.339
5	5	28.860	6.841	5	24.400	4.615	0.744	0.478
6	2	15.150	0.212	3	19.067	6.658	-1.174	0.361
7	2	43.500	0.364	3	47.000	16.083	-0.338	0.759
8	4	15.188	10.136	6	20.367	8.274	-0.912	0.408

BFO

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	30.375	12.023	12	31.500	13.919	-0.192	0.850
2	8	32.500	6.325	17	40.588	11.758	-2.232	0.036
3	19	28.789	8.738	16	21.875	6.640	1.747	0.090
4	9	28.222	11.811	11	23.000	10.237	1.043	0.312
5	5	34.000	4.671	5	32.600	8.813	0.284	0.790
6	2	28.900	10.801	3	32.800	3.464	-0.706	0.580
7	2	33.500	7.771	3	37.667	3.215	-0.718	0.584
8	4	28.500	8.745	6	28.167	2.401	0.786	0.488

SCBE

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	101.218	64.264	12	78.500	37.008	0.988	0.343
2	8	78.658	50.715	17	67.103	38.658	0.573	0.578
3	19	14.303	23.416	16	24.675	22.988	-1.344	0.188
4	9	106.861	104.781	11	71.864	78.180	0.865	0.391
5	5	34.600	27.357	5	48.450	20.373	-0.873	0.381
6	2	0.710	0.884	3	54.865	35.840	-1.167	0.363
7	2	84.710	29.996	3	64.333	15.735	1.329	0.381
8	4	34.063	24.329	6	13.375	8.584	1.601	0.187

CICBE

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	65.298	40.050	12	40.191	24.251	1.580	0.142
2	8	77.748	54.964	17	73.254	31.578	0.215	0.834
3	19	96.550	40.862	16	111.208	43.561	-0.801	0.429
4	9	64.283	27.051	11	80.792	38.318	-0.444	0.662
5	5	98.550	83.284	5	79.576	25.131	0.650	0.540
6	2	90.686	86.184	3	87.561	46.788	-0.718	0.530
7	2	48.894	4.705	3	80.444	13.763	-0.436	0.697
8	4	61.947	29.803	6	138.948	37.583	-2.198	0.061

GHAD

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	1.500	0.756	12	2.292	2.220	-1.140	0.273
2	8	2.250	1.389	17	2.765	1.715	-0.800	0.435
3	19	17.474	11.667	16	12.113	6.678	1.460	0.155
4	9	2.330	1.900	11	4.455	4.845	-1.314	0.194
5	5	2.300	1.643	5	1.400	0.894	0.837	0.434
6	2	11.500	0.707	3	10.667	4.163	0.339	0.784
7	2	1.500	0.707	3	1.333	0.577	0.277	0.808
8	4	8.750	3.403	6	8.000	4.427	0.302	0.771

XDPRAWU

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	4	20.250	8.526	6	23.178	11.248	-0.471	0.651
2	6	19.900	8.684	16	23.100	6.198	-1.256	0.224
3	10	15.117	7.841	16	12.387	7.342	1.082	0.288
4	7	12.108	6.713	5	10.180	3.846	0.740	0.470
5	5	19.020	7.906	5	22.138	8.470	-0.721	0.494
6	2	13.988	8.740	3	12.600	1.375	0.380	0.781
7	2	20.950	7.425	3	22.500	2.121	-0.387	0.775
8	4	15.775	6.200	6	16.833	6.672	-0.270	0.796

XDPRROW

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	5	18.840	8.584	1	13.300	.	N/A	N/A
2	3	17.000	8.880	10	21.070	9.862	-0.790	0.478
3	13	14.492	7.840	11	13.173	8.774	0.381	0.700
4	4	14.500	7.248	6	10.700	8.726	0.836	0.434
5	3	18.067	4.823	2	17.500	2.121	0.466	0.666
6	1	8.000	.	3	12.333	2.309	2.800	0.130
7	1	38.000	N/A	1	34.600	N/A	N/A	N/A
8	2	18.900	2.121	3	13.000	2.606	2.580	0.081

LVLBOS

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	1.875	0.991	12	1.333	0.492	1.433	0.186
2	8	2.250	0.707	17	2.236	0.903	0.044	0.965
3	19	2.632	0.831	16	2.813	1.223	-0.502	0.620
4	9	2.222	0.833	11	1.727	0.786	1.365	0.183
5	5	1.800	0.837	5	1.800	0.447	0.000	1.000
6	2	3.000	1.414	3	3.000	.	0.000	1.000
7	2	3.000	.	3	2.000	1.000	-1.732	0.225
8	4	2.500	1.000	6	2.833	0.753	-0.586	0.584

BOCBOS

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	4.750	1.389	12	4.750	1.422	0.000	1.000
2	8	2.750	0.463	17	3.412	0.870	-2.478	0.021
3	19	2.632	1.116	16	3.188	1.515	-1.218	0.236
4	9	4.333	1.500	11	5.182	0.982	-1.488	0.167
5	5	2.800	0.837	5	3.200	0.447	-0.943	0.382
6	2	3.000	.	3	2.333	0.577	2.000	0.184
7	2	3.000	.	3	3.000	.	N/A	N/A
8	4	2.500	1.000	6	2.833	1.169	-0.482	0.644

BOCBES

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	2.125	1.246	12	1.917	1.379	0.361	0.730
2	8	3.875	0.641	17	3.000	1.275	2.381	0.032
3	19	3.684	1.250	16	3.312	1.621	0.749	0.460
4	9	2.222	1.302	11	2.000	1.414	0.366	0.719
5	5	4.200	0.837	5	3.800	0.447	0.946	0.382
6	2	2.000	.	3	2.333	0.577	1.000	0.423
7	2	3.500	0.707	3	3.667	0.577	-0.277	0.800
8	4	4.250	0.500	6	3.667	1.366	0.954	0.373

XPUC

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	40.063	11.807	12	44.567	28.636	-0.514	0.614
2	8	27.800	13.269	17	36.347	16.112	-1.381	0.190
3	19	22.086	25.194	16	38.206	26.012	-1.855	0.073
4	9	41.271	31.241	11	37.073	25.760	0.324	0.750
5	5	21.320	13.822	5	41.420	12.206	-2.437	0.041
6	2	33.150	43.770	3	25.133	14.100	0.251	0.840
7	2	28.400	8.051	3	38.367	24.558	-0.788	0.504
8	4	44.675	21.979	6	44.617	30.310	0.004	0.997

XPWI

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	13.200	8.262	12	30.450	27.183	-2.058	0.059
2	8	9.575	4.795	17	7.612	7.583	0.788	0.440
3	19	8.268	4.252	16	12.019	10.841	-1.302	0.209
4	9	25.044	26.271	11	26.164	22.155	-0.087	0.924
5	5	9.640	7.460	5	9.020	5.465	0.149	0.885
6	2	9.450	0.071	3	8.033	2.601	0.943	0.445
7	2	4.400	1.838	3	8.933	0.473	-1.807	0.291
8	4	7.150	2.504	6	7.800	6.347	-0.220	0.828

XPCH

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	19.812	26.184	12	33.363	22.152	-1.250	0.229
2	8	47.218	13.638	17	41.800	27.736	0.654	0.520
3	19	67.142	23.289	16	70.425	23.367	-0.416	0.681
4	9	90.444	24.595	11	88.636	28.795	0.651	0.523
5	5	61.400	22.703	5	65.180	9.285	-0.345	0.744
6	2	74.350	29.062	3	85.233	8.752	-0.511	0.660
7	2	13.900	16.263	3	8.567	5.615	0.446	0.724
8	4	72.375	14.952	6	69.863	17.145	0.243	0.815

HUAW

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	0.300	0.240	12	0.253	0.221	0.443	0.664
2	8	0.536	0.170	17	0.502	0.190	0.433	0.671
3	19	0.461	0.281	16	0.424	0.308	0.370	0.714
4	9	0.257	0.122	11	0.228	0.174	0.434	0.669
5	5	0.388	0.152	5	0.482	0.147	-0.982	0.355
6	2	0.351	0.099	3	0.645	0.270	-2.882	0.072
7	2	0.564	0.432	3	0.642	0.227	-0.252	0.833
8	4	0.384	0.147	6	0.626	0.252	-1.919	0.092

TOTAW

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	1.458	1.464	12	2.336	3.068	-0.750	0.450
2	8	2.881	1.827	17	4.794	3.138	-2.081	[illegible]
3	19	2.389	1.414	16	2.178	1.938	0.328	0.747
4	9	1.944	1.408	11	2.148	2.304	-0.198	0.847
5	5	3.100	2.183	5	3.662	2.111	-0.372	0.720
6	2	2.770	0.552	3	4.277	3.086	-0.838	0.489
7	2	6.260	4.687	3	6.740	4.902	-0.108	0.923
8	4	2.718	1.350	6	3.265	1.281	-0.638	0.545

XVPW

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	0.398	0.300	12	0.293	0.243	0.754	0.472
2	8	0.490	0.193	17	0.574	0.372	-0.737	0.469
3	19	0.393	0.245	16	0.270	0.172	1.740	0.091
4	9	0.421	0.382	11	0.198	0.158	1.642	0.131
5	5	0.723	0.341	5	0.695	0.547	0.099	0.925
6	2	0.680	0.339	3	0.365	0.179	1.281	0.374
7	2	0.580	0.535	3	0.954	0.384	-0.841	0.505
8	4	0.345	0.285	6	0.344	0.111	0.008	0.996

XJV

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	10.720	22.885	12	10.874	22.131	-0.015	0.988
2	8	13.070	12.900	17	29.904	12.758	-1.840	0.078
3	19	7.860	12.544	16	8.256	7.450	-0.760	0.453
4	9	9.028	17.240	11	1.993	2.010	1.286	0.234
5	5	27.552	22.068	5	18.280	12.161	0.663	0.526
6	2	3.554	1.442	3	7.064	5.074	-0.736	0.533
7	2	24.698	27.809	3	98.095	48.374	-1.887	0.196
8	4	14.907	8.821	6	12.243	16.570	0.304	0.770

TEMP

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	6	11.167	1.602	7	9.857	2.478	1.148	0.276
2	8	11.500	2.770	17	11.000	3.107	0.496	0.855
3	19	8.895	2.052	14	7.714	1.672	1.263	0.216
4	8	12.000	4.811	5	10.938	3.488	0.506	0.622
5	5	13.100	6.066	5	9.900	0.894	1.532	0.197
6	2	13.500	3.536	3	7.667	2.309	2.050	0.206
7	2	9.500	2.121	3	14.333	2.517	-2.314	0.117
8	3	7.667	1.155	6	9.333	1.966	-1.587	0.157

THAR

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	12186.163	12508.727	12	8347.942	9386.258	0.742	0.472
2	8	9281.580	3640.631	17	25807.912	21377.288	-3.121	0.006
3	11	3225.079	3458.030	16	2881.463	1805.952	0.750	0.458
4	9	8057.778	8853.888	11	2251.101	1837.005	1.548	0.158
5	6	18046.180	12925.897	5	10580.920	8143.292	0.881	0.417
6	2	6231.400	1152.016	3	4081.833	3557.171	0.061	0.956
7	2	28198.700	3060.723	3	27861.833	24007.129	0.038	0.973
8	4	7107.650	4592.134	6	6051.933	3821.818	0.379	0.718

TPLAR

Super Guild	Undisturbed n	Undisturbed Mean	Undisturbed SD	Disturbed n	Disturbed Mean	Disturbed SD	T Value	P Value
1	8	3604.650	3218.813	12	2555.042	3808.432	0.883	0.816
2	8	3808.163	1947.393	17	8813.829	8110.828	-1.494	0.150
3	19	912.728	1007.181	16	1032.375	776.696	-0.390	0.698
4	9	1367.267	1478.487	11	671.545	664.401	1.367	0.148
5	5	2457.200	1181.476	5	4360.780	1083.909	-2.717	0.027
6	2	1010.850	485.287	3	1960.767	1604.891	-1.006	0.400
7	2	3380.850	2470.276	3	8541.367	8229.929	-0.838	0.631
8	4	2629.325	1775.184	6	2583.867	2282.800	0.027	0.979

Appendix B

RESULTS OF T-TESTS COMPARING INDEPENDENT VARIABLES AMONG DISTURBED AND UNDISTURBED SITES (Continued)

Super Guild	PPLAR Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
1	8	34.136	21.267	12	16.958	19.572	1.827	0.089
2	8	41.588	12.681	17	34.329	29.387	0.862	0.398
3	19	22.653	14.210	16	34.381	15.669	-2.243	0.032
4	9	27.000	22.250	11	23.355	20.858	0.375	0.712
5	5	19.680	8.202	6	47.960	17.128	-3.308	0.017
6	2	19.150	5.162	3	36.800	9.528	-2.846	0.080
7	2	12.550	10.112	3	20.633	19.853	-0.596	0.582
8	4	39.775	19.212	6	38.183	14.877	0.052	0.960

Super Guild	IMWW Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
1	8	16.038	9.849	12	13275	10.074	0.542	0.597
2	8	15.763	9.192	17	24994	9.471	-3.607	0.002
3	19	7.637	5.023	16	7725	4.080	0.082	0.936
4	9	11.178	7.910	11	8308	3.596	1.706	0.117
5	5	19.140	1.173	6	16.460	3.248	0.676	0.526
6	2	11.000	1.828	3	11.433	4.880	-0.129	0.908
7	2	25.250	1.909	3	23833	7.769	0.332	0.787
8	4	14.675	1.290	6	12950	5.718	0.440	0.675

Super Guild	MPLMDI Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
1	8	21.462	10.558	12	23.000	7.971	-0.351	0.732
2	8	14.750	6.303	17	20.335	6.872	-2.228	0.039
3	19	11.664	6.974	16	9.400	4.622	1.166	0.251
4	9	13.467	9.365	11	11.318	6.774	0.578	0.574
5	5	19.320	8.599	6	16.900	3.906	0.520	0.624
6	2	20.200	8.505	3	16.800	10.197	0.458	0.660
7	2	26.050	8.960	3	21.700	6.944	0.448	0.703
8	4	12.075	3.773	6	13.417	6.740	-0.446	0.667

Super Guild	XDPRPD Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
1	7	20.629	8.288	6	23.400	10.946	-0.565	0.58
2	8	16.937	6.058	17	23.794	8.467	-1.421	0.171
3	19	14.400	5.636	15	12.387	7.209	0.864	0.395
4	9	11.363	5.718	8	8.678	3.901	1.441	0.171
5	5	20.140	7.685	6	22.100	5.465	-0.464	0.654
6	2	11.550	4.313	3	12.900	1.419	0.206	0.86
7	2	21.650	8.980	3	23.350	0.911	-0.268	0.83
8	4	16.425	8.849	6	16.817	5.491	-0.378	0.71

Super Guild	XPERWD Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
1	8	7.862	7.493	12	11.192	11.750	-0.700	0.493
2	8	9.262	4.412	17	10.476	10.335	-0.411	0.685
3	19	8.379	4.618	16	8.813	5.818	0.310	0.759
4	9	10.378	8.863	11	12.427	11.871	-0.421	0.679
5	5	8.140	9.013	5	10.520	4.100	-0.537	0.612
6	2	6.900	0.566	3	8.667	7.448	-0.479	0.679
7	2	10.150	8.858	3	6.667	5.450	0.566	0.631
8	4	10.500	7.247	6	10.750	7.621	-0.052	0.960

Super Guild	XPHPH Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
7	6.850	1.963	6	9.589	5.252	-0.848	-0.414	
8	11.021	1.148	17	12.180	12.264	-0.297	0.769	
10	8.357	1.085	16	6.756	3.267	1.093	0.283	
6	12.763	11.888	8	8.110	8.777	0.796	0.440	
5	8.118	1.433	5	12.042	6.330	-0.772	0.465	
2	8.250	1.061	3	9.314	8.182	-0.264	0.815	
2	13.834	1.179	3	19.183	11.198	-0.471	0.718	
4	10.798	1.895	6	12.983	10.019	-0.397	0.703	

Super Guild	XPILDI Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
8	0.200	0.400	12	4.600	14.166	-1.064	0.316	
9	13.663	23.036	17	17.312	23.493	-0.367	0.718	
10	35.008	20.661	16	22.312	22.194	1.748	0.090	
9	12.922	21.813	11	2.336	4.734	1.363	0.196	
5	44.040	34.955	5	6.800	7.899	2.436	0.066	
2	35.150	8.132	3	33.333	16.917	0.183	0.861	
2	0.000	.	3	0.400	0.361	1.922	0.195	
4	55.450	19.257	6	32.533	22.480	1.723	0.127	

Super Guild	XPSF Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
8	59.438	42.309	12	62.642	39.265	-0.187	0.85	
6	10.850	5.835	17	28.647	17.963	-1.222	0.23	
10	9.853	14.054	16	27.650	34.259	-1.945	0.067	
9	46.888	37.656	11	62.662	40.546	-0.768	0.441	
5	10.240	10.283	6	12.160	8.009	-0.378	0.720	
2	12.050	4.172	3	7.933	8.259	0.863	0.444	
2	43.550	47.447	3	17.667	16.58	0.738	0.561	
4	8.775	10.451	6	14.833	14.23	-0.776	0.461	

Super Guild	TNPWCW Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
1	8	1.362	1.897	12	2.328	3.080	-0.687	0.307
2	8	2.610	1.553	17	4.785	3.139	-2.105	0.046
3	19	2.317	1.391	16	2.101	1.665	0.380	0.707
4	9	1.878	1.422	11	2.102	2.307	-0.207	0.839
5	5	2.614	1.970	5	3.614	2.142	-0.768	0.465
6	2	2.700	0.552	3	4.237	3.124	-0.786	0.504
7	2	6.260	4.837	3	8.740	4.802	-0.108	0.923
8	4	2.750	1.370	6	3.177	1.301	-0.550	0.601

Super Guild	OWPJ Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
4	13.683	11.733	7	8.523	7.778	0.796	0.471	
7	4.607	2.806	17	6.344	7.505	-1.014	0.321	
10	18.292	41.430	13	7.301	4.832	1.115	0.280	
8	13.416	12.387	8	32.148	54.407	-0.975	0.358	
5	12.680	1.754	5	8.058	9.564	0.811	0.430	
2	4.175	1.247	3	2.963	0.413	3.946	0.028	
2	4.455	1.600	3	6.183	1.693	-1.461	0.351	
4	6.812	2.720	6	8.065	3.983	0.859	0.416	

Super Guild	RTOTPR Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
8	99.563	25.816	12	99.964	0.471	-0.967	0.360	
8	96.649	3.925	17	99.547	1.436	-2.026	0.078	
10	97.962	3.777	16	95.153	6.467	1.228	0.234	
9	97.364	6.962	11	98.206	3.096	-0.337	0.743	
5	88.530	18.259	5	98.308	3.786	-1.309	0.254	
2	100.000	.	3	98.373	1.880	-1.491	0.275	
2	100.000	.	3	100.000	.	N/A	N/A	
4	99.780	2.420	6	96.667	1.750	0.804	0.447	

Super Guild	XVOLALL Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
8	0.298	0.314	12	0.292	0.248	0.052	0.960	
8	0.494	0.185	17	0.572	0.371	-0.608	0.492	
10	0.403	2.389	16	0.301	0.223	1.266	0.206	
9	0.617	0.388	11	0.194	0.159	1.632	0.133	
5	0.743	0.376	5	0.714	0.539	0.103	0.921	
2	0.500	0.339	3	0.352	0.181	1.268	0.370	
2	0.500	0.535	3	0.954	0.361	-0.641	0.505	
4	0.343	0.266	6	0.360	0.125	-0.110	0.918	

Super Guild	CVHPD Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
1	7	24.292	13.058	6	18.422	12.903	0.984	0.336
2	8	25.713	8.135	17	24.312	9.665	0.463	0.655
3	19	28.628	12.031	15	28.500	18.740	0.022	0.983
4	8	32.425	14.822	9	25.411	11.334	1.086	0.297
5	6	38.340	15.382	5	35.960	11.316	0.279	0.788
6	2	20.600	9.617	3	25.667	15.273	-0.473	0.669
7	2	38.000	2.051	3	43.000	15.770	-0.537	0.643
8	4	27.050	15.801	6	26.017	9.957	0.117	0.911

Super Guild	OVHPD Undisturbed n	Mean	SD	Disturbed n	Mean	SD	T Value	P Value
7	23.986	11.221	6	28.317	6.028	-0.415	0.696	
8	36.800	21.224	13	29.700	13.528	0.822	0.429	
10	42.108	11.560	15	32.193	11.883	1.967	0.061	
8	41.425	12.891	9	43.122	21.204	-0.292	0.843	
5	26.660	11.884	5	33.000	8.660	-0.777	0.463	
2	42.600	11.243	3	32.300	14.504	0.670	0.577	
2	56.900	34.184	2	38.150	14.779	0.623	0.625	
4	20.675	1.843	6	38.167	10.837	-2.917	0.026	