CHAPTER 5
ASSESSMENT MODEL FUNCTIONS & VARIABLES

5.1 Overview

The Technical and Assessment teams identified 14 functions performed by riverine ecosystems along the South Coast of Santa Barbara County. These functions fall into four logical groups: hydrology, soils and biogeochemistry, plant community, and faunal support/ habitat (Table 5.1). All of these functions are performed at some level at all sites within the reference domain.

A total of 28 variables are used to describe each of the 14 functions discussed in this Draft Guidebook (Table 5.2). Additional variables were considered by the A-team during model development, but these variables were not included in the Draft Guidebook because (1) they were not characteristic to all sites, or (2) reference system data associated with the variable did not show a trend that could be used to predict ecosystem functioning. Variables representing a given function sometimes differ among the three subclasses found in the reference domain. These changes are due to the unique characteristics of each defined subclass. We used data from reference standard sites or the best representative site for a given variable, stratified by subclass, to determine reference standard conditions for each function (Table 5.4). After the reference standard condition had been established, data from other reference sites (non-reference standard sites) were stratified to account for the natural range of variation for a given variable.

Each of the 14 ecosystem functions (Table 5.1) and each of the 28 variables (Table 5.2) are fully described in the following sections. See Table 5.3 for relation of variables to functions. Descriptions of each of 14 ecosystem functions are found in section 5.2 and include the following information

Information Provided in Section 5.2 for each function

1. Definition
2. Rationale for the function
3. Variables used to assess the function
4. Characteristics and processes that influence the function
5. Rationale for selection of the variables used
6. Rationale and formulae used to estimate the function

Descriptions of each of the 28 variables include the following information:

Information found in section 5.3 for each variable

1. Definition
2. Rationale for selection of the variable
3. A protocol for measuring the variable in the field
4. Location of reference system data in appendices
5. Scaling rationale—a description of how reference system data were used to scale the variable
6. Confidence—a description of the author's confidence that reasonable logic and/or data support scaling
7. Scaling—the Authors provide a rationale for use of a variable each time it is called by a function

Table 5.1 List of Functions by Category

FUNCTION		DESCRIPTION
Hydrology		
1.	Energy Dissipation	The transformation and/or reduction of the kinetic energy of water as a function of the roughness of the landscape and channel morphology, and vegetation.
2.	Surface and Subsurface Water Storage and Exchange	The presence of soil and/or geologic materials within the creek ecosystem, including the hyporheic zone, that have physical characteristics suitable for detention, retention, and transmission of water.
3.	Landscape Hydrologic Connections	The maintenance of the natural hydraulic connectivity among source areas of surface and subsurface flow to riverine waters/wetlands and other down gradient waters/wetlands.
4.	Sediment Mobilization, Storage, Transport, and Deposition	The mobilization, transport, and deposition of sediment as determined by characteristics (morphology) of the channel as well as the timing, duration, and amount of water delivered to the channel.
Biogeochemistry		
5.	Cycling of Elements and Compounds	Short- and long-term transformation of elements and compounds through abiotic and biotic processes that convert chemical species (*e.g.,* nutrients and metals) from one form, or valence, to another.
6.	Removal of Imported Elements and Compounds	The removal of imported nutrients, contaminants, and other elements and compounds in surface and groundwater.
7.	Particulate Detention	The deposition and retention of inorganic and organic particulates (>0.45μm) from the water column, primarily through physical processes.
8.	Organic Matter Transport	The export of dissolved and particulate organic carbon from a wetland. Mechanisms include leaching, flushing, displacement, and erosion.
Plant community		
9.	Plant Community	The physical characteristics and ecological processes that maintain the indigenous living plant biomass.
10.	Detrital Biomass	The process of production, accumulation, and dispersal of dead plant biomass of all sizes.
Faunal support/habitat		
11.	Spatial Structure of Habitats	The capacity of waters/wetlands to support animal populations and guilds through the heterogeneity of structure of vegetative communities.
12.	Interspersion and Connectivity of Habitats	The capacity of waters/wetlands to permit aquatic, semi-aquatic, and terrestrial organisms to enter and leave a riverine ecosystem via large, contiguous plant communities to meet life history requirements.
13.	Distribution & Abundance of Vertebrate Taxa	The capacity of waters/wetlands to maintain characteristic density and spatial distribution of invertebrates (aquatic, semi-aquatic and terrestrial).
14.	Distribution & Abundance of Invertebrate Taxa	The capacity of waters/wetlands to maintain the density and spatial distribution of invertebrates (aquatic, semi-aquatic and terrestrial).

Table 5.2 Definition of Variables for Riverine Ecosystems in the South Coast Santa Barbara County Domain

Table 5.2 Definition of Variables for Riverine Ecosystems along the South Coast of Santa Barbara County (*continued)*

	VARIABLE		DEFINITION
13.	$V_{PATCHAREA}$	**Area of Patches**	The relative area of habitat patches, as calculated from the ETM Habitat Patch Analysis map, within the 1000' radius VAA surrounding the PAA.
14.	$V_{PATCHCONTIG}$	**Contiguity of Patches**	The contiguity of habitat patches, as generated from the ETM Habitat Patch Contiguity Analysis, within the proposed project site sub-watershed.
15.	$V_{PATCHNUM}$	**Number of Patches**	The number of habitat patches, calculated from the ETM Habitat Patch Analysis map, within the 1000' radius VAA surrounding the PAA
16.	V_{RATIO}	**Ratio of Native to Non-Native Plant Species**	Ratio of the dominant plant taxa within the VAA that are native to SCBC to those that have been introduced to the region.
17.	V_{REGEN}	**Regeneration**	Regeneration is the reestablishment of plants from seedlings, saplings, and clonal shoots within the VAA.
18.	$V_{RESIDPOOL}$	**Residual Pool**	The number and average distance between residual pools >10ft^2 in area and ≥0.5 ft deep (at their deepest point) within the active channel at low flow to base flow conditions.
19.	V_{SED}	**Sediment Deposition**	Refers to the sources and amount of sediment delivery and deposition to waters/wetlands from upgradient landscape positions.
20.	V_{SHADE}	**Shade Over the Channel below Ordinary High Water**	Tree, shrub and undergrowth vegetation canopy cover overhanging the active stream channel.
21.	$V_{SHRUBCC}$	**Shrub Canopy Cover**	Percent canopy cover of shrubs (multiple stemmed woody species) within the VAA.
22.	V_{SNAGS}	**Snags**	Basal area of standing dead trees (snags) (≥ 3" DBH).
23.	$V_{SOILINT}$	**Soil Profile Integrity**	A measure of the presence and condition of representative soil profiles (soil horizons) within the VAA.

Table 5.3 Relationship of Variables to Functions

Table 5.4 Reference Standard Conditions for Riparian Ecosystems along the South Coast of Santa Barbara County

	VARIABLE	REFERENCE STANDARD CONDITION
1.	V_{ASIGN}	**All Subclasses:** ≥ 4 classes of animals or animal signs **or** ≥ 2 indicator species (animals or animal signs) **and** no evidence of human alteration of the VAA within the last 50 years.
2.	$V_{BUFFCOND}$	**All Subclasses:** Dominant land use / condition within the buffer is unaltered by human activity.
3.	$V_{BUFFCONT}$	**All Subclasses:** The vegetated buffer (rural, 100 feet; urban, 50 feet) is continuous on both sides of the stream channel, throughout the VAA.
4.	$V_{BUFFWIDTH}$	**All Subclasses:** (a) If zoned "rural" by Santa Barbara County, then the average vegetated buffer width within the VAA is ≥ 100 ft on both sides of the stream channel; **or** (b) If zoned "urban" by Santa Barbara County, then the average vegetated buffer width within the VAA is ≥ 50 ft on both sides of the stream channel.
5.	$V_{CHANROUGH}$	**High and Moderate Gradient:** ≥25% of the channel cross sectional area is occupied by natural roughness elements such as boulders, imbedded logs, bedrock, etc. and there is no evidence of historic human disturbance of channel roughness. **Low Gradient:** ≥ 5 % of the channel cross sectional area is occupied by natural roughness elements such as boulders, embedded logs, bedrock, etc. and there is no evidence historic human disturbance of channel roughness
6.	V_{CWD}	**All Subclasses:** The total CWD volume below OHW and within the PAA is ≥ 100 ft^3 **and** the AA has been unaltered by human activities.
7.	V_{DECOMP}	**All Subclasses:** The total number of decomposition classes below OHW is ≥ 3 and the mode (most frequent occurrence) of decomposition class is ≥ 3.
8.	V_{EMBED}	**All Subclasses:** Larger class channel bed material is embedded ≥50% along its vertical axis in either skeletal sands (sand with >35% gravel, cobbles and stones) or a cobble and stone matrix that is mixed with little to no loamy material
9.	V_{HERB}	**All Subclasses:** (a) Average herbaceous cover > 3% and ≤ 10% **and** (b) Cover class midpoint for the dominant herb species is not > 38% **and** (c) vegetation below top of bank is unaltered by human activities.
10	V_{INCWD}	**All Subclasses:** Total CWD volume below OHW and within the VAA is ≥ 100 ft^3 **and** VAA has been unaltered by human activities.
10.	$V_{LANDUSE}$	**High & Moderate Gradients:** The project site sub-watershed is dominated by land use classes that are composed of a high proportion (> 85%) of native chaparral/forest (ETM Class 6) and native chaparral/woodland (ETM Class 5) **and** no evidence of human alteration of the reference site sub-watershed (*i.e.* hiking trails, abandoned fire or ranch roads, old/abandoned homesteads, etc. are acceptable under this condition) **Low Gradient**: The project site sub-watershed is dominated by land use classes that are composed of > 65% native chaparral/forest (ETM Class 6), native chaparral/woodland (ETM Class 5), and scrub/shrub/coastal chaparral (ETM Class 4) **and** no evidence of human alteration of the project site sub-watershed *(i.e.*, hiking trails, abandoned fire or ranch roads, old/abandoned homesteads, *etc*. are acceptable under this condition).
11.	$V_{LONGPROF}$	**All Subclasses:** The longitudinal channel slope within the VAA study reach (i.e. upstream or downstream seven times the OHW channel width from the main cross section) **or** upstream **or** downstream from the PAA study reach is unaffected by human

Table 5.4 Reference Standard Conditions for Riparian Ecosystems along the South Coast of Santa Barbara County, *continued*

Table 5.4 Reference Standard Conditions for Riparian Ecosystems along the South Coast of Santa Barbara County, *continued*

	VARIABLE	REFERENCE STANDARD CONDITION
23.	$V_{SOILINT}$	**High and Moderate Gradient:** Representative VAA soil profile is weakly to moderately developed (*i.e.* different horizons are discernable), intact and entirely undisturbed by human activities (e.g. roads, debris basins, agriculture). Typically the soil profile has a weakly developed A, and in some cases a weak Bw horizon, some structure within the upper part, and a moist color value **and** chroma ≤ 3 in the upper part. The soil particle size class is generally loamy skeletal or sandy skeletal. **Low Gradient:** Representative VAA soil profile is weakly to strongly developed (*i.e.* different horizons are discernable), intact and entirely undisturbed by human activities. Typically the soil profile has an A, Bw or Bg, and/or Cg horizon(s) and a moist color value **and** chroma ≤ 3 in the upper part. A soil particle size class of loamy (or finer) is generally present.
24.	V_{STRATA}	**All Subclasses:** (a) Average number of strata ≥ 2.0 **and** (b) Vegetation below top of bank is unaltered by human activities.
25.	V_{SURFIN}	**All Subclasses:** Surface hydraulic connections into the VAA from the adjacent landscape are unaltered by human activities. No manipulations of the surface hydraulic connections leading to, or within the VAA are present.
26.	V_{TREEBA}	**High Gradient:** (a) Tree basal area ≥ 100 $ft.^2$/acre **and** (b) vegetation below top of bank is unaltered by human activity. **Moderate Gradient:** (a) Tree basal area > 70 $ft.^2$/acre **and** (b) vegetation below top of bank is unaltered by human activity. **Low Gradient:** (a) Tree basal area ≥ 50 $ft.^2$/acre **and** (b) vegetation below top of bank is unaltered by human activity.
27.	V_{TREECC}	**High and Moderate Gradient:** (a) Average tree canopy cover ≥ 80% **and** (b) vegetation below top of bank is unaltered by human activities. **Low Gradient:** (a) Average tree canopy cover ≥ 50% **and** (b) vegetation below top of bank is unaltered by human activities.
28.	V_{VINE}	**All Subclasses:** (a) Average vine canopy cover ≥ 60% and ≤ 75% **and** (b) vegetation below top of bank is unaltered by human activities.

Table 5.5 Indices of Functions for Riverine Waters/Wetlands along the South Coast of Santa Barbara County

The formulae above are used to derive a single index or level of functioning for each identified function from multiple variable scores. They have no mathematical meaning beyond their usefulness in integrating the variables that pertain to each function.

5.2
Functions

5.2.1.
Hydrologic Functions

ENERGY DISSIPATION

Definition

Energy Dissipation is the transformation and/or reduction of the kinetic energy of water as a function of the roughness of the landscape and channel morphology, and vegetation.

Rationale for the Function

This function not only pertains to rate of flow through wetlands, but is also related to how energy is expressed in the water flowing into, through, and out of stream channels. Energy dissipation results in the allocation of potential energy to other forms of kinetic energy as water moves into, through, or out of a water/wetland. Riverine waters/wetlands derive potential energy from precipitation that falls throughout the watershed. This potential energy is converted to kinetic energy as water is moved through stream systems under the force of gravity. The primary forms of kinetic energy are water flow, sediment mobilization and transport, heat, and sound. Energy dissipation occurs as a function of resistance (*i.e.*, roughness). Thus, channel morphology, bed materials, and vegetation are critical components of this function. In some low gradient systems, connectivity to secondary channels and off-channel depressions can dissipate hydrologic energy by providing additional area over which high flows can spread. Dissipated energy expressed as scour holes and sediment deposition may also enhance dynamic and long term surface water storage by creating topographic relief and surface roughness. An offsite hydrologic expression of the energy dissipation function is the reduction in flood peak, flood wave celerity, and improved water quality *(i.e.*, less sediment). Channelized streams are designed to increase channel velocity and minimize overbank flow. The resultant channel flow, unless artificially stabilized, will undercut banks and the channel will begin a meandering process to dissipate the energy.

In high-energy streams, common in mountainous regions, large woody debris and boulders are moved in the channel and onto floodplains. As a result of energy dissipation within the channel and associated wetlands, hydraulic work on channel bed and banks is lessened and the system is more stable. For example, a recently cleared riparian area will have few trees in place for woody debris to lodge against. Energy that would otherwise be dissipated in riparian vegetation will be transferred to channel scour, and movement/deposition of sediment. Similar hydrologic processes occur in lower energy systems with less obvious expressions, but no less important to the functioning of waters/wetlands.

Variables Used to Assess Energy Dissipation

The following variables all represent ecosystem components that act to dissipate energy by providing roughness to the channel system.

Channel Roughness ($V_{CHANROUGH}$)
In-Channel Coarse Woody Debris (V_{INCWD})
Buffer Condition ($V_{BUFFCOND}$)
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Width ($V_{BUFFWIDTH}$)
Herbs (V_{HERB})
Shrubs (V_{SHRUB})
Trees (V_{TREEBA})

Channel Roughness ($V_{CHANROUGH}$)

Channel roughness represents the hydraulic resistance produced by natural, immobile features of the channel system below ordinary high water. Resistance to flow is created by biotic and abiotic elements within the channel. Abiotic elements include bedrock, stones, boulders, etc. Biotic components of channel roughness include large, buried and/or fixed coarse woody debris. Channel roughness affects temporal and spatial flow conditions (*e.g.* turbulence, water velocity, flow paths, *etc*.) in riverine ecosystems, and influences the kinetic energy of water flowing in the channel. Thus, channel roughness has direct effects on the reallocation or dissipation of energy.

In-Channel Coarse Woody Debris (V_{INCWD})

Coarse Woody Debris represents the input of roughness elements by return of structural elements of the tree stratum to the forest floor and riverine ecosystem by the mortality of whole trees. Competition, defoliation, and decadence can return trees to the forest floor or stream channel at slower rates between fires. Coarse wood reaching the soil surface or riverine ecosystem undergoes slow decomposition. Therefore, the woody structure and roughness element of coarse woody debris has a more long-term presence.

Buffer Contiguity, Condition, and Width ($V_{BUFFCONT}$) ($V_{BUFFCOND}$) ($V_{BUFFWIDTH}$)

Buffer Contiguity, Condition, and Width represent the contribution of the riverine buffer to the reallocation of energy by affecting (1) the timing, duration, and amount of water delivered to the channel, (2) roughness elements within the riverine ecosystem, and (3) the development and integrity of the vegetation communities within the stream buffer. Riverine ecosystem buffers have multiple vegetation strata in reference standard conditions.

Hydrologic Functions
Energy Disipation

Variables Used to Assess Energy Dissipation *continued*

Herb Canopy Cover (V_{HERBCC})

Herb Canopy Cover represents roughness elements of the herbaceous stratum within the riverine ecosystem. The herbaceous stratum is present within the riverine ecosystem, including buffers in the reference standard condition.

Shrub Canopy Cover (V_{SHRUB})

Shrub Canopy Cover represents roughness elements of the shrub stratum within the riverine ecosystem. The shrub stratum is present within the riverine ecosystem, including buffers in the reference standard condition.

Tree Basal Area (V_{TREEBA})

Tree basal area represents roughness elements provided by the tree stratum within the riverine ecosystem. The tree stratum provides roughness elements in (1) the live standing stock, (2) snags, and (3) individual mortality and input of coarse woody debris to the stream channel. Tree strata are present within the riverine ecosystem, including buffers in the reference standard condition.

Tree cover characterizes the riparian corridors in the reference standard condition but is not necessarily characteristic of other community types within the reference domain. In addition, trees provide shade with consequent effects on soil temperature (Brown 1963), moisture, and rates of production and decomposition, all of which have direct affects on roughness elements provided by herbs and shrubs.

Index of Function:

$$[(V_{INCWD}) + (V_{HERBCC} + V_{SHRUBCC} + V_{TREEBA})/3 + (V_{BUFFCONT} + V_{BUFFCOND} + V_{BUFFWIDTH})/3 + (V_{CHANROUGH})]/4$$

SURFACE AND SUBSURFACE WATER STORAGE AND EXCHANGE

Definition

Surface and Subsurface Water Storage and Exchange is the presence of soil and/or geologic materials within the creek ecosystem, including the hyporheic zone, which have physical characteristics suitable for detention, retention, and transmission of water.

Rationale for the Function

Within a stream ecosystem water may be collected, detained, or stored as (1) surface water above the soil surface, (2) shallow subsurface water within the soil profile or geologic stratum, including pore water in the saturated zone, and soil moisture in the unsaturated zone. It is the pore space within sediment, riparian soils, and various geologic strata that provides the volume for storing water, and allows for the exchange of water between surface and shallow subsurface compartments. The absorption and storage of subsurface water occurs within a wide distribution of pore sizes. A broad range of pore sizes within the porous media increases the time of travel of water by providing more tortuous routes of travel and greater resistance to flow. Subsurface storage also reduces surface water depth and slows the release of water to the stream (in contrast to surface flow directly to the channel). Subsurface storage within deep soil, or geologic strata, helps to maintain base flows.

A soil or geologic stratum's potential for subsurface storage is a function of the size and abundance of the soil pore spaces and antecedent degree of saturation. Small pore sizes have the ability to adsorb and hold water for long periods of time. The degree of saturation of a soil or geologic stratum is affected by:

1. prior flooding events
2. precipitation and other inputs
3. the position of the water table
4. pore space

These factors determine the actual storage capacity at a particular point in time. Frequent flooding, or a constant input of water (either ground or surface water), may render soils and geologic strata incapable of additional water storage. Alterations of hydrology that create inundation (*e.g.*, beaver activity) or saturation to the surface also alter this function.

Hydrologic Functions
Surface and Subsurface Water Storage and Exchange

Variables Used to Assess Surface and Subsurface Water Storage and Exchange

The following variables represent abiotic ecosystem components that can transmit, store, and exchange water between surface and subsurface environments.

Soil Profile Integrity ($V_{SOILINT}$)
Sediment Deposition (V_{SED})
Residual Pools ($V_{RESIDPOOL}$)

Soil Profile Integrity ($V_{SOILINT}$)

The development of the soil profile over time results in an increase in:

1. soil structure and surface infiltration rates
2. finer soil texture within the subsurface horizons due to the physical and chemical weathering of soil particles and primary minerals
3. organic matter content due to inputs from vegetation and processing by microbial communities
4. pore space.

The distribution of particle size (texture) and the accumulation of organic matter within the soil, allows water to be held at different energies, or tension (*e.g.*, matric potential). In finer textured soils water is held with greater energy (tension) providing longer contact time between water and mineral and organic components. Thus, well developed, intact soil profiles generally have greater porosity and water holding capacities than younger or disturbed soils formed from the same parent material. Additionally, finer textured soil horizons are generally subsurface horizons and therefore facilitate subsurface water storage. In finer textured soils, water is held within the smaller pores and, therefore, is in contact with the most reactive components of the soil (*e.g.*, clays, organic compounds, and mineral and organic colloids). An intact soil profile is an indirect assessment of subsurface water storage.

Sediment (V_{SED})

Sediments are mineral and organic materials that have pore space and thus, are capable of water storage and transmission. Sediments transmit, detain, and store water in much the same manner as soils, and can possess many of the characteristics of soils (*e.g.* organic matter accumulation, biogeochemical processing, sorption, elemental exchange). Just as in soil, the pore size distribution within the sediment determines the rate of water movement in the sediment, and the amount of water held or retained after stream flow has ceased. Alteration of the amount and rate of sediment delivery to waters/ wetlands can have profound affects on Surface and Subsurface Water Storage and Exchange.

Hydrologic Functions
Surface and Subsurface Water Storage and Exchange

Residual Pools ($V_{RESIDPOOL}$)

Residual pools of various sizes and depths are common in intact High, Medium, and Low gradient streams. These pools form specialized and relatively unique areas within the stream ecosystem where a number of ecosystem processes occur. There are direct and indirect hydrologic connections from the residual pools to other surface and subsurface compartments within the riverine ecosystem with varying degrees of connectedness to in-channel and subsurface flows (inputs and outputs). At low flow to base flow conditions, the shallow surface and subsurface water exchanges that occur between pools and stream banks create relatively moist to saturated pool-edge microsites. Residual pools can have bedrock and/or sediment substrate. Sediment substrate within residual pools functions to store water subsurface, and to exchange water with surface flows. The presence of residual pools can be used as a direct assessment of the channels ability to detain and store surface water.

Index of Function: $(V_{SED} + V_{SOILINT} + V_{RESIDPOOL})/3$

Hydrologic Functions

LANDSCAPE HYDROLOGIC CONNECTIONS

Definition

Landscape Hydrologic Connections maintain the natural hydraulic connectivity among source areas of surface and subsurface flow to riverine waters/wetlands and other down gradient waters/wetlands.

Rationale for the Function

Riverine wetlands usually form along low-gradient reaches of streams, resulting in relatively low rates of subsurface flow through the wetland. Subsurface flows, both unsaturated and saturated (groundwater), are important linkages between uplands, wetlands, and streams (see for example Roulet 1990 and O'Brian 1980). Landscape hydrologic connections are the hydrologic connectivity of contributing areas, to riverine waters/wetlands, to other down gradient waters/wetlands. The low-order ephemeral streams have land-dominated hydrographs so the timing, duration, and amount of water delivered to the channel is dependent upon the condition of the watershed and the buffer. The high-order seasonal streams have land- and channel-dominated hydrographs so the timing, duration, and amount of water delivered to the channel is dependent upon the condition of the watershed and the buffer as well as the condition of the upgradient channels. The high-order seasonal and perennial streams depend upon intact connections from the upper portions of the watershed to maintain flow and sediment transport characteristics.

Variables Used to Assess Landscape Hydrologic Connections

The following variables represnet abiotic and biotic ecosystem components that are involved in the timing, duration, and amounts of water delivered to the channel and the connectivity to down gradient waters/wetlands.

Soil Profile Integrity ($V_{SOILINT}$)
Surface Water In (V_{SURFIN})
Channel Longitudinal Profile ($V_{LONGPROF}$)
Land Use ($V_{LANDUSE}$)
Buffer Condition ($V_{BUFFCOND)}$)
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Width ($V_{BUFFWIDTH}$)

Soil Profile Integrity ($V_{SOILINT}$)

The soil profile has voids (*i.e.* pore space) that are capable of transporting, detaining and storing fluids, including water. Intact soil profiles in riparian areas and riverine ecosystems provide hydraulic connectivity to down gradient waters/wetlands. The distribution of particle size (texture) and the accumulation of soil organic matter within the soil, allows water to be held at different energies, or tension (*e.g.*, matric potential) and thus transported at different rates. Tortuosity within the soil medium reduces water energy and transports and delivers water at a metered rate. Thus, Soil Profile Integrity is an important variable for Surface and Subsurface Water Storage and Exchange.

Hydrologic Functions: Landscape Hydrologic Connections

Channel Longitudinal Profile
($V_{LONGPROF}$)

The integrity of the natural longitudinal profile of the deepest part of the channel cross-section (*i.e.*, thalweg) is a necessary physical element of an intact riverine ecosystem. Maintenance of the integrity of the natural longitudinal profile of channel systems is a fundamental physical feature that, when combined with channel width, depth, water volume, and bedload materials, defines the ability of the channel system to maintain hydrologic connectivity with down gradient waters/wetlands, riparian soils, and the natural floodplain. The maintenance of hydraulic connectivity allows the riverine ecosystem to maintain characteristic hydrologic regimes through all phases of the hydrograph.

Some altered sites within the regional wetland subclass have impacted the integrity of the longitudinal profile of the stream channel. Manipulation of the longitudinal profile of channel systems (*e.g.*, installation of in-channel dams or diversion structures, water bars, bridges, culverts, *etc.*) in southern Santa Barbara County immediately leads to adjustments in the ability of the channel system to allocate kinetic energy and to perform characteristic functions such as Landscape Hydrologic Connections.

Buffer Contiguity, Condition, and Width
($V_{BUFFCONT}$)
($V_{BUFFCOND}$)
($V_{BUFFWIDTH}$)

Buffer Contiguity, Condition, and Width are biotic variables representing the affects of the riverine buffer on the timing, duration, and amount of water delivered to the channel. The higher order seasonal and perennial streams within the medium and high grade subclass depend upon intact connections from the upper portions of the watershed to maintain flow and sediment transport characteristics. Thus, the riverine buffer exerts effects on the timing, duration, and amount of flow and sediment transport, as well as hydrologic connectivity to higher order, down gradient channels. Riverine ecosystem buffers have multiple vegetation strata and are intact in reference standard conditions.

Land Use
($V_{LANDUSE}$)

Description Pending

Surface Water In
(V_{SURFIN})

Description Pending

Index of Function:

$$[V_{LONGPROF} + V_{LANDUSE} + V_{SOILINT} + V_{SURFIN} + (V_{BUFFCONT} + V_{BUFFCOND} + V_{BUFFWIDTH})/3]/5$$

Hydrologic Functions

SEDIMENT MOBILIZATION, STORAGE, TRANSPORT, AND DEPOSITION

Definition

Sediment Mobilization, Storage, Transport, and Deposition is determined by characteristics (morphology) of the channel as well as the timing, duration, and amount of water delivered to the channel.

Rationale for the Function

The mobilization, transport, and deposition of sediment influences the channel pattern, dimension, and profile, channel bed materials, and vegetation of the riverine water/wetland. The characteristics of sediment mobilization, transport, and deposition are determined by the timing, duration, and amount of water delivered to the channel. The low-order ephemeral streams have land-dominated hydrographs so the timing, duration, and amount of water delivered to the channel is dependent upon the condition of the watershed and the buffer. The high-order seasonal streams have land- and channel-dominated hydrographs so the timing, duration, and amount of water delivered to the channel is dependent upon the condition of the watershed and the buffer as well as the condition of the upgradient channels. Stable channels have characteristic patterns, dimensions, profiles, and channel bed materials. Intact channel buffers help to maintain channel bank vegetation and bank stability.

Variables Used to Assess Sediment Mobilization, Storage, Transport, and Deposition

The following variables can be used to assess Sediment Mobilization, Storage, Transport, and Deposisiton because they affect the timing, duration, and amounts of water delivered to the channel and the degree of channel roughness.

Channel Roughness ($V_{CHANROUGH}$)
Embeddedness of Large Channel Materials (V_{EMBED})
Sediment Deposition (V_{SED})
Buffer Condition ($V_{BUFFCOND}$)
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Width ($V_{BUFFWIDTH}$)
Herbs (V_{HERBCC})
Shrubs ($V_{SHRUBCC}$)
Trees (V_{TREEBA})

Hydrologic Functions
Sediment Mobilization, Storage, Transport, and Deposition

Channel Roughness ($V_{CHANROUGH}$)

The stream channel, and channel riparian areas can be assessed for the ability to detain or transport organic and inorganic particles by estimating the degree of immobile features within the channel system that offer hydraulic resistance. Therefore, ($V_{CHANROUGH}$) represents an indirect assessment of (1) the amount of sediment that may be retained/detained and/or potentially transported by a specific reach of channel, and (2) the potential for detention and/or transport within similar channel reaches throughout the subclass.

Embeddedness of Large Channel Materials (V_{EMBED})

The stream channel, and channel riparian areas can be assessed for the ability to detain and/or transport organic and inorganic particles by observing (1) the amount of accumulated sediment within specific channel reaches, (2) the size fraction of those particles, and (3) the degree to which those particles have buried, or embedded, larger clasts within the stream channel. Therefore, (V_{EMBED}) represents a direct assessment of the amount and size class of particles retained/detained and/or potentially transported by a specific reach of channel. (V_{EMBED}) is an indirect assessment of the potential for similar channel reaches throughout the subclass to retain or detain sediment.

Sediment Deposition (V_{SED})

The stream channel and channel riparian areas can sometimes be assessed for the ability to detain or export organic and inorganic particles by the amount, or lack, of accumulated sediment within specific channel reaches. Therefore, (V_{SED}) is a direct assessment of the amount of particulates retained/detained and/or potentially transported by a specific reach of channel. (V_{SED}) is an indirect assessment of the potential for similar channel reaches throughout the subclass to retain, detain, and/or transport sediment and particulates.

Buffer Contiguity, Condition, and Width ($V_{BUFFCONT}$) ($V_{BUFFCOND}$) ($V_{BUFFWIDTH}$)

The development and integrity of the vegetation communities within the stream buffers has a direct affect on the detention of particulates within the system. Elements and compounds are temporarily retained/detained in soils and sediments, but the critical attributes for detention of particulates are found within the riparian and stream buffer vegetation communities and include live and dead plant material (*i.e.* live trees and CWD). Riverine ecosystem buffers have multiple vegetation strata in reference standard conditions. The buffer vegetation is capable of detaining particulates by (1) filtering of the water column within the channel, (2) filtering water incoming to the channel, and (2) providing roughness elements through mortality of larger vegetation.

Hydrologic Functions
Sediment Mobilization, Storage, Transport, and Deposition

Herbs (V_{HERBCC}) The herb component of riverine ecosystems contributes to the deposition and detention of organic and inorganic particulates by contributing properties of roughness to (1) the stream channel, (2) channel riparian areas, and (3) the associated floodplain. Altered sites sometimes have no herbaceous cover (*e.g.*, agricultural tillage, hardened channels and/or banks, fill). This situation contrasts with natural perturbation from fire, which produces abundant herbaceous cover by native plants. Some altered sites support non-native herbaceous cover that provides roughness elements. Upon cessation of active land uses, altered sites can re-enter natural successional pathways and move toward reference standard conditions. Although rapid shrub and tree invasion will quickly reduce herbaceous dominance, the Herbs variable is an important component for assessing Particulate Detention in the riverine ecosystems within the reference domain.

Shrubs ($V_{SHRUBCC}$) The shrub component of riverine ecosystems contributes to the deposition and detention of organic and inorganic particulates by contributing properties of roughness to (1) the stream channel, (2) channel riparian areas, and (3) the associated floodplain. Shrubs occur in most community types in the reference domain. However, altered sites sometimes have no shrub cover (*e.g.*, agricultural tillage, hardened channels and/or banks, fill). This situation contrasts with natural perturbation from fire, which can produce abundant cover by native shrubs. Some altered sites support non-native shrub cover that provides roughness elements. Upon cessation of active land uses, altered sites may re-enter natural successional pathways and move toward reference standard conditions. Rapid shrub invasion will produce additional roughness elements within the riverine ecosystems in the reference domain.

Trees (V_{TREEBA}) The tree component of riverine ecosystems contributes to the deposition and detention of organic and inorganic particulates by contributing properties of roughness to (1) the stream channel, (2) channel riparian areas, and (3) the associated floodplain. Tree cover characterizes the riparian corridors in the reference standard condition but is sparse or absent in other community types within the reference domain. In addition, trees provide shade with consequent effects on soil temperature (Brown 1963) and moisture and accompanying effects on rates of production and decomposition, which has affects on roughness elements provided by herbs and shrubs.

Index of Function:

$$[(V_{HERBCC} + V_{SHRUBCC} + V_{TREEBA})/3 + (V_{BUFFCONT} + V_{BUFFCOND} + V_{BUFFWIDTH})/3 + V_{EMBED} + V_{SED} + V_{CHANROUGH})]/5$$

5.2.2 Biogeochemical Functions

CYCLYING OF ELEMENTS & COMPOUNDS

Definition

Cycling of Elements and Compounds includes the abiotic and biotic processes that cycle elements and convert compounds (*e.g.,* nutrients and metals) from one form, or valence, to another; primarily recycling processes.

Rationale for the Function

Cycling of elements and compounds is mediated by biotic and abiotic components, and is a fundamental ecosystem process. Net primary productivity, in which nutrients are taken up by plants, and detritus turnover, in which nutrients are released for renewed uptake by plants and microbes, comprise the biotic components of elemental cycling. Abiotic components are linked inextricably to the microbially mediated (biogeochemical) processes that drive the oxidation-reduction reactions that alter elements and compounds. Sources of these abiotic components are, the soil profile, eolian processes that input nutrients and particulates, and hydrologic processes that input nutrients and particulates to the system. Net effects of elemental cycling are balanced between gains through import processes, and losses through hydrologic export, efflux to the atmosphere, and long-term retention in soil, sediment, and persistent biomass. Retention of elements and compounds on site decreases the probability of their export to down-gradient aquatic ecosystems and diminishes nutrient loading. Elements and compounds retained on site also contribute to water quality in waters and wetlands adjacent to, and down gradient from the project assessment area.

Cycling of Elements and Compounds differs from the function, Removal of Nutrients and Elements in that elements and compounds are recycled rather than removed. Most relatively intact and unpolluted riverine wetlands do not substantially reduce the concentration of inorganic nitrogen, phosphorus, or other constituents downstream unless loading rates are well above background. This is because considerable recycling occurs such that uptake and release are in relatively close balance (Finn 1980). Recycling is critical to maintaining low concentrations of elements and nutrients in flowing water (Elder 1985). The concept of recycling is similar to nutrient spiraling in streams (Elwood *et al.* 1983). Specific nutrients or elements are not singled out for this function. In situations where more detailed assessment of nutrient-related functions is desirable, the cycles of elements such as nitrogen and phosphorus could be assessed separately.

Biogeochemical Functions
Cycling of Elements and Compounds

Variables Used to Assess Cycling of Elements and Compounds

The following variables represent biotic and abiotic components of the ecosystem that are involved in biological and geochemical processes. The biotic components of riverine ecosystems cycle elements and nutrients through (1) uptake of nutrients from soil and water, (2) biomass accumulation, and (3) litter production. Abiotic cycling occurs in soil horizons and stream sediments.

In-Channel Coarse Woody Debris (V_{INCWD})
Out of Channel Coarse Woody Debris (V_{OFFCWD})
Herbs (V_{HERBCC})
Shrubs ($V_{SHRUBCC}$)
Trees (V_{TREEBA})
Buffer Condition ($V_{BUFFCOND)}$)
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Width ($V_{BUFFWIDTH}$)
In-Channel Woody Decomposition (V_{DECOMP})
Soil Profile Integrity ($V_{SOILINT}$)
Sediment Deposition (V_{SED})

Coarse Woody Debris (V_{INCWD}) (V_{OFFCWD})

Coarse Woody Debris is a biotic variable representing return of elements and compounds stored in the tree strata to the forest floor and riverine ecosystem by litterfall and individual mortality. Competition, defoliation, and decadence can return trees and shrubs to the forest floor at low rates between fires.

Coarse wood reaching the soil surface undergoes slow decomposition and releases stored elements and compounds for uptake by the plant community. Some components of wood resist decomposition and may remain in the pool of stored carbon and nutrients for long periods of time. A change in characteristic input of coarse wood can alter nutrient cycles.

Herb Canopy Cover (V_{HERBCC})

Herbaceous litter decomposes more readily than woody plant litter. Thus, the herbaceous stratum thus is adapted for rapid turnover of biomass and associated nutrients. Herbaceous cover interacts with nutrient cycling through effects on soil temperature and moisture.

Shrub Canopy Cover ($V_{SHRUBCC}$)

Shrubs occur in most community types within the reference domain. In addition, shrub cover interacts with nutrient cycling through the effects of cover on soil temperature and moisture.

Biogeochemical Functions
Cycling of Elements and Compounds

Tree Basal Area (V_{TREEBA})

Tree cover characterizes the riparian corridors in the reference standard condition but is not necessarily characteristic of other community types (*e.g.* chaparral) within the reference domain. Elements entering tree stratum nutrient pools will turn over more slowly with stand age. In addition, trees provide shade with consequent effects on soil temperature (Brown, 1963) and moisture and accompanying effects on rates of production and decomposition of organic compounds.

Buffer Contiguity, Condition, and Width ($V_{BUFFCONT}$) ($V_{BUFFCOND}$) ($V_{BUFFWIDTH}$)

The cycling of elements and compounds occurs between soil, water, vegetation, and the atmosphere. Elements and compounds are temporarily retained/ detained in soils and sediments, but the critical processes and attributes occur in soil and vegetation. The buffer vegetation is capable of uptake and return of elements and compounds. Additionally, the buffer filters incoming surface and shallow subsurface water. Buffer vegetation uptakes, transforms, and temporarily stores elements and compounds, and in some cases provides oxygen to the rooting zone.

Decay Class (V_{DECOMP})

The presence of coarse woody debris is an indicator for the dynamics of the cycling of elements and compounds. Coarse woody debris in various stages of decay provides substrate for a variety of soil microbes (*e.g*. bacteria, actinomycetes, fungi, and algae), and soil meso- and macro-fauna (*e.g.* arthropods, mollusks) which further break down highly carbonaceous detritus. The further breakdown and decay of coarse woody debris makes smaller organic particulates, elements, and compounds available for transport, export, and/or uptake by plants and animals.

Soil and Sediment ($V_{SOILINT}$) (V_{SED})

Abiotic processes occurring in soil horizons and stream sediments include chemical transformations of elements and nutrients in response to redox potentials. Reduction and oxidation processes biogeochemically cycle elements and compounds (*e.g.,* N, S, C, Mn, Fe,) between different forms (valence states). For example, phosphorus (P) co-precipitates with Mn and Fe oxides under oxidizing conditions, but becomes soluble under reducing conditions. Redox transformations biogeochemically cycle elements and compounds (*e.g.,* N, S, C, Mn, Fe, in various valence states).

Index of Function:

$$[(V_{SOILINT} + V_{SED})/2 + (V_{INCWD} + V_{OFFCWD})/2 + (V_{HERBCC} + V_{SHRUBCC} + V_{TREEBA})/3 + (V_{BUFFCONT} + V_{BUFFCOND} + V_{BUFFWIDTH})/3 + (V_{DECOMP})]/5$$

Biogeochemical Functions

REMOVAL OF IMPORTED ELEMENTS AND COMPOUNDS

Definition

Removal of Imported Elements and Compounds is the removal of imported nutrients, contaminants, and other elements and compounds from surface and groundwater.

Rationale for the Function

This function takes a very broad approach to both the elements and compounds of interest and the mechanisms by which they are removed. This is in contrast to most research on the topic, which is conducted on one element or mechanism at a time and often includes expensive and/or time consuming methodologies that quantify the elements or compounds of interest. Elements herein include macronutrients essential to plant growth (nitrogen, phosphorus, potassium, *etc.*) as well as other elements such as heavy metals (zinc, chromium, *etc*.) that can be toxic at high concentrations. Compounds include herbicides, pesticides, and other imported materials. The soil profile, sediments, and vegetation are the main components in the Removal of Imported Elements and Compounds function. Mechanisms of removal include sorption, sedimentation, denitrification, burial, decomposition to inactive forms, microbial transformation, uptake and incorporation into long-lasting woody and long-lived perennial herbaceous biomass, and similar processes.

The functioning of wetlands as interceptors of nonpoint source pollution is well documented (reviewed by Johnston 1991) and additional studies have shown that wetland/riparian systems serve as sinks for nutrients and contaminants from upland sources (Lowrance *et al*. 1984). Riverine wetlands, particularly those in headwater positions, are strategically located to intercept nutrients and contaminants before they reach streams (Brinson 1988). We use the term "removal" to imply the relatively long-term accumulation or permanent loss of elements and compounds from incoming water sources. This can be contrasted with the Nutrient Cycling function in which a portion of the elements is recycled on a time frame of one year or less.

Variables Used to Assess Removal of Imported Elements and Compounds

The following variables represent biotic and abiotic components of the ecosystem that are involved in biological and geochemical processes. The removal of imported elements and compounds is a function of (1) the timing, duration, and amount of water delivered to the riverine ecosystem, (2) the development or integrity of the soil profile, and (3) the development and integrity of the vegetation communities within the stream buffer. The biotic components of riverine ecosystems remove elements and compounds through (1) uptake from soil and water, (2) biomass accumulation, and (3) and partitioning into soil organic matter.

Herbs (V_{HERBCC})
Shrubs ($V_{SHRUBCC}$)
Trees (V_{TREEBA})
Buffer Condition ($V_{BUFFCOND)}$)
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Width ($V_{BUFFWIDTH}$)
Soil Profile Integrity ($V_{SOILINT}$)
Sediment Deposition (V_{SED})
Stream Longitudinal Profile ($V_{LONGPROF}$)

Herb Canopy Cover (V_{HERBCC})

Characteristic herbs (forbs, graminoids, ferns, and fern allies) allocate a large proportion of production to below ground biomass. Thus, the herbaceous stratum is adapted for uptake of elements and compounds. Herbaceous cover also interacts with nutrient uptake through effects on soil temperature and moisture.

Shrub Canopy Cover ($V_{SHRUBCC}$)

Shrubs occur in most community types within the reference domain. In addition, shrub cover interacts with nutrient uptake through the effects of cover on soil temperature and moisture.

Tree Basal Area (V_{TREEBA})

Tree basal area characterizes the riparian corridors in the reference standard condition but is not necessarily characteristic of other community types within the reference domain. Elements entering tree stratum nutrient pools will turn over more slowly with stand age. In addition, trees provide shade with consequent effects on soil temperature (Brown 1963) and moisture and accompanying effects on rates of production and decomposition of organic compounds.

Biogeochemical Functions
Removal of Imported Elements and Compounds

Buffer Contiguity, Condition, and Width ($V_{BUFFCONT}$) ($V_{BUFFCOND}$) ($V_{BUFFWIDTH}$)

Elements and compounds are temporarily retained/detained in soils and sediments, but the critical processes and attributes of removal occur in soil and vegetation. The buffer vegetation is capable of removing elements and compounds by filtering of the water column, and biological uptake. Buffer vegetation uptakes, transforms, and provides for temporary storage of elements and compounds.

Soil and Sediment ($V_{SOILINT}$) (V_{SED})

Abiotic processes occurring in soil horizons and stream sediments that help remove imported elements and compounds include sorption and chemical transformations of elements and nutrients in response to redox potentials, soil particle size, and mineralogy. Reduction and oxidation processes biogeochemically transform some minerals, elements, and compounds (*e.g.,* N, S, C, Mn, Fe, FeOOH) between different forms and/or valence states. For example, phosphorus co-precipitates with Mn and Fe oxide minerals under oxidizing conditions but becomes soluble under reducing conditions. Redox transformations and soil/sediment particles alter and/or remove some elements and compounds (*e.g.,* N, S, C, metals, minerals).

Channel Longitudinal Profile ($V_{LONGPROF}$)

The integrity of the natural longitudinal profile of the deepest part of the channel cross-section (*i.e*. thalweg) is a necessary physical element of an intact riverine ecosystem. Maintenance of the integrity of the natural longitudinal profile of channel systems is a fundamental physical feature that, when combined with channel width, depth, water volume, and bedload materials, defines the ability of the channel system to perform work, including the removal of imported elements and compounds. Thus, changes in channel slope will lead to changes in cross sectional and longitudinal channel geometry (*e.g*. width, depth, degree of entrenchment, sinuosity, *etc*.) These responses have important direct and collateral effects on the ability of the riverine ecosystem to maintain characteristic hydrologic regimes through all phases of the hydrograph.

Index of Function:

$$[(V_{HERBCC} + V_{SHRUBCC} + V_{TREEBA})/3 + (V_{BUFFCONT} + V_{BUFFCOND} + V_{BUFFWIDTH})/3 + (V_{SOILINT} + V_{SED})/2 + V_{LONGPROF}]/4$$

PARTICULATE DETENTION

Definition

Particulate Detention is the deposition and retention of inorganic and organic particulates (>0.45µm) from the water column, primarily through physical processes.

Rationale for the Function

Flooding is the major source of inorganic particulates for floodplains and riparian areas. Floodplains of smaller streams also receive sediments due to overland flow from adjacent uplands. Once waterborne sediment has been transported to a floodplain, velocity reduction normally occurs due to surface roughness and increasing cross-sectional area of discharge (Nutter and Gaskin 1989). This leads to a reduction in the capacity of water to transport suspended sediments, so particulates settle. The best evidence of this function is the presence of retained sediments in depositional layers. This evidence is particularly diagnostic when deposition is recent and can be related to a specific flood event.

Retention applies to particulates arising from both onsite and offsite sources, but excludes *in situ* production of organic matter. The Particulate Detention function contrasts with Cycling of Elements and Compounds and Removal of Imported Elements and Compounds because the emphasis is more dependent on physical processes (*e.g.*, sedimentation and particulate removal). Sediment retention occurs through burial and chemical precipitation (*e.g.*, removal of phosphorus by Fe^{3+}). Dissolved forms may be transported as particles after undergoing sorption and chelation (*i.e.*, metals mobilized with organic compounds).

The same hydrodynamics that facilitate sedimentation may also capture and retain existing organic particulates. For example, deposition of silt by winter floods following autumn litterfall appears to reduce the potential for leaves to become suspended by currents and exported (Brinson 1977).

Because sources of water and depth of flooding vary greatly among stream orders (Brinson 1993b), there may be a need to stratify subclasses by stream order to reduce this natural source of variation. Headwater streams that accumulate large amounts of sediments may represent a disturbed condition incapable of sustaining the function. Excessive retention of particulates, as in reservoirs, may create a “sediment shadow” downstream from dams (Rood and Mahoney 1990) or debris basins.

Biogeochemical Functions
Particulate Detention

Variables Used to Assess Particulate Detention

The following variables are involved in physical and biological processes facilitating the detention of organic and inorganic particulates. The detention of organic and inorganic particulates from the water column is essentially a physical process. Detention of particulates is a function of the:

1. timing, duration, and amount of water delivered
2 roughness elements within the riverine ecosystem
3. development and integrity of the vegetation communities within the stream buffer.

The biotic components of riverine ecosystems contribute to the deposition and detention of organic and inorganic particulates by contributing properties of roughness to (1)the stream channel, (2) channel riparian areas, and (3) the associated floodplain. Abiotic components of riverine ecosystems contribute to the deposition and detention of organic and inorganic particulates by contributing physical properties of roughness to the stream channel and channel riparian areas.

Herbs (V_{HERBCC})
Shrubs ($V_{SHRUBCC}$)
Trees (V_{TREEBA})
Buffer Condition ($V_{BUFFCOND)}$)
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Width ($V_{BUFFWIDTH}$)
In-channel Coarse Woody debris (V_{INCWD})
Sediment Deposition (V_{SED})
Channel Roughness ($V_{CHANROUGH}$)
Embeddedness of Large Channel Materials (V_{EMBED})

Herb Canopy Cover (V_{HERBCC})

The herbaceous layer provides surface roughness and is important in trapping and holding particulates. The decomposition of herbs contributes to the development of a litter layer which provides additional surface roughness.

Shrubs Canopy Cover ($V_{SHRUBCC}$)

Shrubs occur in most community types in the reference domain. However, altered sites sometimes have no shrub cover (*e.g.*, avocado orchards, hardened channels and/or banks, fill). This situation contrasts with natural perturbation from fire, which can produce abundant cover by native shrubs by the end of the first decade after fire (Dallman, 1998). Upon cessation of active land uses, altered sites can potentially re-enter natural successional pathways and move toward reference standard conditions.

Biogeochemical Functions
Particulate Detention

Tree Basal Area (V_{TREEBA})

Tree cover characterizes the riparian corridors in the reference standard condition but is not necessarily characteristic of other community types (*e.g.* chaparral) within the reference domain. Trees provide shade with consequent effects on soil temperature (Brown 1963) and moisture and accompanying effects on rates of production and decomposition, which has affects on roughness elements provided by herbs and shrubs.

Buffer Contiguity, Condition, and Width ($V_{BUFFCONT}$) ($V_{BUFFCOND}$) ($V_{BUFFWIDTH}$)

Elements and compounds are temporarily retained/detained in soils and sediments, but the critical attributes for detention of particulates are found within the riparian and stream buffer vegetation communities and include live and dead plant material (*i.e.* live trees and coarse woody debris). The buffer vegetation is capable of detaining particulates by (1) filtering of the water column within the channel, (2) filtering water incoming to the channel, and (2) providing roughness elements through mortality of larger vegetation.

In-Channel Coarse Woody Debris (V_{INCWD})

Coarse Woody Debris is a biotic variable representing the input of roughness elements by return of structural elements of the tree stratum to the forest floor and riverine ecosystem by individual mortality of whole trees. Competition, defoliation, and decadence can return trees and shrubs to the forest floor or stream channel at low rates between fires. Coarse wood reaching the soil surface or riverine ecosystem undergoes slow decomposition. Thus, the woody structure and roughness element of coarse woody debris has a more long-term presence. Thus, Coarse Woody Debris is an important component for assessing Particulate Detention in the reference domain.

Sediment Deposition (V_{SED})

Sometimes stream channels and riparian corridors can be assessed for their ability to detain organic and inorganic particles by observing the amount, or lack, of accumulated sediment within specific channel reaches. Therefore, (V_{SED}) is a: direct assessment of the amount of particulates retained/detained by a specific reach of channel; and an indirect assessment of the potential for similar channel reaches throughout the subclass to retain or detain sediment and particulates.

Biogeochemical Functions
Particulate Detention

Variables Used to Assess Particulate Detention, *continued*

Embeddedness of Large Channel Materials (V_{EMBED})

Stream channels and riparian corridors can be assessed for the ability to detain organic and inorganic particles by observing (1) the amount of accumulated sediment within specific channel reaches, (2) the size fraction of those particles, and (3) the degree to which those particles have buried, or embedded, larger clasts within the stream channel. Therefore, (V_{EMBED}) represents a direct assessment of the amount and size class of particles retained/detained by a specific reach of channel, and an indirect assessment of the potential for similar channel reaches throughout the subclass to retain or detain sediment.

Channel Roughness ($V_{CHANROUGH}$)

Stream channels and riparian corridors can be assessed for the ability to detain organic and inorganic particles by estimating the degree of immobile features within the channel system that offer hydraulic resistance. Therefore, $V_{CHANROUGH}$ represents an indirect assessment of the amount of sediment that may be retained/detained by a specific reach of channel, and the potential for detention within similar channel reaches throughout the subclass.

Index of Function:

$$[(V_{HERBCC} + V_{SHRUBCC} + V_{TREEBA})/3 + (V_{BUFFCONT} + V_{BUFFCOND} + V_{BUFFWIDTH})/3 + (V_{CHANROUGH}) + (V_{SED}) + (V_{EMBED})]/5$$

ORGANIC MATTER EXPORT

Definition

Organic Matter Export is the export of dissolved and particulate organic carbon from a wetland. Mechanisms include leaching, flushing, displacement, and erosion.

Rationale for the Function

Waters/wetlands export organic carbon at higher rates per unit area than terrestrial ecosystems (Mulholland and Kuenzler 1979) in part because surface water has greater contact time with organic matter in litter and surface soil. Organic carbon is exported from waters/wetlands in dissolved and particulate forms. Mechanisms of organic carbon export include leaching, displacement, and erosion. Sources of organic carbon include herbaceous vegetation both in the water/wetland and in the buffer, as well as organic matter incorporated into the soil profile. Export of organic carbon from the riverine water/wetland is dependent upon the status/condition of the hydrologic connection to down gradient waters/wetlands.

While the molecular structure of most organic matter is not well known because of its chemical complexity (Stumm and Morgan 1981, Paul and Clark 1989), organic matter nevertheless plays important roles in geochemical and food web dynamics. For example, organic carbon can complex with a number of relatively immobile metallic ions which, in turn, facilitates their transport in soil (Schiff *et al*. 1990). Organic carbon is a primary source of energy for microbial food webs (Edwards 1987; Edwards and Meyer 1986) that form the base of the detrital food web in aquatic ecosystems. These factors, in combination with the close proximity of wetlands to aquatic ecosystems, make wetlands critical sites for supplying both dissolved and particulate organic carbon.

Biogeochemical Functions
Organic Matter Export

Variables Used to Assess Organic Matter Export

The following variables represent biotic and abiotic components of the ecosystem that are involved in the biological and physical processes that export organic carbon.

In-Channel Coarse Woody Debris (V_{INCWD})
Herbs (V_{HERBCC})
Shrubs ($V_{SHRUBCC}$)
Trees (V_{TREECC})
Buffer Condition ($V_{BUFFCOND}$)
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Width ($V_{BUFFWIDTH}$)
Woody Decomposition (V_{DECOMP})
Longitudinal Profile ($V_{LONGPROF}$)

In-Channel Coarse Woody Debris (V_{INCWD})

The biotic components of riverine ecosystems export organic matter through (1) defoliation, (2) decadence, and (3) litter production. Coarse Woody Debris is a biotic variable representing the return of elements, and organic compounds stored in the tree stratum to the forest floor and riverine ecosystem by litterfall and mortality of whole trees. Once returned to the riverine ecosystem, these elements and organic compounds are available for export.

Coarse wood reaching the soil surface undergoes slow decomposition and releases stored elements and compounds for uptake by the plant community and export from the system. Some components of wood resist decomposition and may remain in the pool of stored carbon and nutrients and be exported in that form. A change in characteristic input of coarse wood can alter the export of organic particulates.

Herb Canopy Cover (V_{HERBCC})

The biotic components of riverine ecosystems export organic matter through (1) defoliation, (2) decadence, and (3) litter production. In this function, Herb Canopy Cover is a biotic variable representing the return of elements, and organic compounds stored in the herbaceous stratum to the forest floor and riverine ecosystem by litter production and mortality. Once returned to the riverine ecosystem, these elements and organic compounds are available for export.

Biogeochemical Functions
Organic Matter Export

Shrub Canopy Cover ($V_{SHRUBCC}$)

The biotic components of riverine ecosystems export organic matter through (1) defoliation, (2) decadence, and (3) litter production. In this function, Shrubs is a biotic variable representing the return of elements and organic compounds stored in the shrub stratum to the forest floor and riverine ecosystem by litterfall and mortality. Once returned to the riverine ecosystem, these elements and organic compounds are available for export.

Tree Basal Area (V_{TREEBA})

The biotic components of riverine ecosystems export organic matter through: (1) defoliation, (2) decadence, and (3) litter production. Trees is a biotic variable representing the return of elements, and organic compounds stored in the tree stratum to the forest floor and riverine ecosystem by litterfall and individual mortality. Once returned to the riverine ecosystem, these elements and organic compounds are available for export.

Tree cover characterizes the riparian corridors in the reference standard condition but is not necessarily characteristic of other community types within the reference domain. Elements and compounds entering the tree stratum should turn over more slowly with stand age, but are eventually available for export. In addition, trees provide shade with consequent effects on soil temperature (Brown 1963) and moisture and accompanying effects on rates of production and decomposition of organic matter.

Buffer Contiguity, Condition, and Width ($V_{BUFFCONT}$) ($V_{BUFFCOND}$) ($V_{BUFFWIDTH}$)

The export of organic matter is a function of the biota within the riverine ecosystem and the physical ability of the riverine system to export organic matter (*i.e.* hydraulic connections to down gradient waters/wetlands). Riverine ecosystem buffers have multiple vegetation strata in reference standard conditions. The various strata within the buffer uptake and return elements and compounds, and contribute detrital biomass for export.

Decay Class (V_{DECOMP})

The presence of coarse woody debris is an indicator for the dynamics of carbon cycling. The various stages of decay of coarse woody debris provides substrate for a variety of soil microbes (*e.g.* bacteria, actinomycetes, fungi, and algae), and soil meso- and macro-fauna (*e.g.* arthropods, mollusks) which further break down highly carbonaceous detritus. The breakdown and decay of coarse woody debris makes smaller organic particulates available for transport and export. Thus, the decay variable for woody debris is an important component for assessing Export of Organic Matter in riverine ecosystems within the reference domain.

Biogeochemical Functions
Organic Matter Export

Variables Used to Assess Organic Matter Export, *continued*

Channel Longitudinal Profile ($V_{LONGPROF}$)

The integrity of the natural longitudinal profile of the deepest part of the channel cross-section (*i.e.* thalweg) is a necessary physical element of an intact riverine ecosystem. Maintenance of the integrity of the natural longitudinal profile of channel systems is a fundamental physical feature that, when combined with channel width, depth, water volume, and bedload materials, defines the ability of the channel system to perform work, including the export of organic matter. Thus, changes in channel slope will lead to changes in cross sectional and longitudinal channel geometry (*e.g.* width, depth, degree of entrenchment, sinuosity, *etc.*) These responses have important direct and collateral effects on the ability of the riverine ecosystem to maintain characteristic hydrologic regimes through all phases of the hydrograph.

Index of Function:

$$[(V_{INCWD}) + (V_{DECOMP}) + (V_{HERBCC} + V_{SHRUBCC} + V_{TREEBA})/3 + (V_{BUFFCONT} + V_{BUFFCOND} + V_{BUFFWIDTH})/3 + (V_{LONGPROF})]/5$$

5.2.3 Plant Community Functions

PLANT COMMUNITY MAINTENANCE

Definition

Plant Community Maintenance is defined as the physical characteristics and ecological processes that maintain the indigenous living plant biomass.

Rationale for the Function

The living plant biomass converts solar radiation and carbon dioxide into complex organic molecules that serve as the basis for heterotrophic organisms of all food webs. As such, plants provide energy to drive microbial food webs, provide corridors for migration and movement between habitats, provide structural complexity that forms feeding, resting, thermal cover habitat, and food for migratory and resident animals. Additionally, plants provide seeds and other propagules for regeneration and succession following fire, floods, and catastrophic mass failure, such as debris flows.

Vegetation accounts for most of the biomass of riverine wetlands, and the physical characteristics of living and dead plants are closely related to ecosystem functions associated with hydrology, nutrient cycling, and the abundance and diversity of animal species, as mentioned above (Gregory *et al.* 1991). However, vegetation is not static and species composition and physical characteristics change in space and time in response to natural and anthropogenic influences (Shugart 1987).

The importance of plant communities to riverine ecosystems can be understood by considering what happens when vegetation is removed or highly disturbed (Harris and Gosselink 1990). Removal or severe disturbance of riparian vegetation can lead to a change in the structure of macroinvertebrate communities (Hawkins, Murray, and Anderson 1982), a decrease in the species diversity of stream ecosystems, a decline in the local and/or regional diversity of animals associated with riverine corridors, a deterioration of downstream water quality, and a significant change in river/stream hydrology (Gosselink *et al*. 1990).

Plant Community Functions
Plant Community Maintenance

Variables Used to Assess Plant Community Maintenance

Herbs (V_{HERBCC})
Shrubs ($V_{SHRUBCC}$)
Tree Canopy Cover(V_{TREECC})
Ratio of Natives to Non-natives (V_{RATIO})
Regeneration (V_{REGEN})
Vines (V_{VINECC})
Strata (V_{STRATA})
Tree Basal Area (V_{TREEB})

Herb Canopy Cover (V_{HERBCC})

The herb canopy cover variable represents the percent cover of the ground surface that is occupied by herbaceous species (*i.e.*, forbs, graminoids, ferns, and fern allies). Herbaceous cover is a convenient and reliably repeatable estimate of spatial continuity of vegetation, and is a standard vegetation sampling procedure.

Many riverine forests possess an herbaceous flora that occurs in discrete clumps or patches on the forest floor. Considerable variation in composition and distribution may exist in the herbaceous layer, depending upon: time of year (*e.g.*, spring ephemerals in forests of the eastern United States), successional stage (*e.g.,* more extensive herbaceous cover immediately after fire than when a fire has not occurred in the recent past), and degree of disturbances from wind storms, floods, debris flows, *etc*., and various human activities. Additionally, herbaceous species can occur in greater abundance in areas where there is more incident solar radiation due to gaps in the tree canopy. In the riverine wetland systems of the central California coast, this relatively high light environment occurs most often within the vicinity of the active channel, where there is a break in the canopy between the trees growing on each side of the stream channel.

Shrub Canopy Cover ($V_{SHRUBCC}$)

Canopy cover is an estimate of spatial continuity and dominance in the vegetation layer of interest. Many riverine forests possess a relatively discontinuous shrub canopy, but considerable variation may exist in the shrub layer depending upon successional stage and degree of disturbances from wind storms, floods, debris flows, *etc*., and various human activities. Shrub species can occur in greater abundance in areas where there is more incident solar radiation due to gaps in the canopy. In these riverine wetland systems, this most often occurs on the floodplain where tree falls create gaps in the upper canopy layer.

Plant Community Functions
Plant Community Maintenance

Tree Canopy Cover (V_{TREECC})

Tree canopy cover is an estimate of spatial continuity and dominance in the upper layers of a forest canopy. Many riverine forests possess a relatively continuous canopy, but considerable variation can be expected due to impacts of disturbances from wind storms, floods, and various human activities, such as clearing, selective logging, etc. Canopy gaps also are present in most mature forests, but these gaps are created by normal mortality processes and should not necessarily be considered as a sign of direct anthropogenic disturbance.

Ratio of native to non-native taxa (V_{RATIO})

The presence of nonnative taxa, including ornamentals, cultivated species, and agricultural or urban weeds, is often used as a measure of the degree of disturbance to an ecosystem (D'Antonio *et al*. 1999). Because California has a rich native weed flora, the presence of particular Eurasian species, such as sweet clover (*Melilotus indica*), Smilo grass (*Pitatherum miliaceum*), among many others, usually indicates anthropogenic disturbance, rather than a natural form of disturbance, such as fire. Recently, D'Antonio and her colleagues (1999) have argued that a relationship between site disturbance and the invasion by nonnative species exists, but not unequivocally. Some nonnatives require an opening in the native community structure for successful invasion, while other species may simply be ruderal opportunists that are transient members of undisturbed ecosystems, but more permanent members of disturbed ones. Given the basic assumption, however, that the presence of nonnatives species is indicative of human alterations to the landscape, a ratio of native to nonnative taxa provides a general indication of the degree to which riparian systems have been influenced by anthropogenic factors.

Regeneration from seedlings/saplings and/or clonal shoots (V_{REGEN})

Death is a natural process in ecosystems, and the maintenance of plant communities requires replacement of individuals that die. The understory of a mature plant community typically contains small and/or young individuals (saplings/seedlings) of species that occur in the forest canopy. Saplings and seedlings of understory species (shrubs, herbs, and vines) in stable communities also will be present. Therefore, species composition of the understory vegetation is useful in predicting what a plant community will be like in the future, especially for sites that have been disturbed and are undergoing secondary succession (Sharitz, Schneider, and Lee 1990).

Plant Community Functions
Plant Community Maintenance

Variables Used to Assess Plant Community Maintenance, *Continued*

Tree Basal Area (V_{TREEBA})

In this guidebook, the tree basal area variable is one of two variables to describe the dominant photosynthetic organisms of the riparian forested ecosystems of south Santa Barbara county. Forested communities generally have volumes of standing timber that are characteristic of a mature system (Curtis 1959, Avery 1967, and Mueller Dombois and Ellenberg 1974). Recognition of the relative dominance of the tree strata in forested communities is important because trees in several stages of succession regulate micro-climatic conditions that affect terrestrial vegetation community development, and conditions in the aquatic environment (*e.g*., stream temperature). In addition, tree canopies and root structures help to protect riparian sites from erosion due, for example, to raindrop energy or high energy surface flows. Trees provide horizontal and vertical structure that, in turn, present (a) opportunities for the movement of animals into and out of riparian ecosystems and (b) several forms of cover (*e.g*., resting , hiding, escape, thermal). Trees produce detritus that is incorporated into the soil profile, and into aquatic food webs.

Vine Canopy Cover (V_{VINES})

Many riverine forests possess a vine layer that has both vertical and horizontal attributes. The life history strategy of vines is to seek light ("phototropic"), there by climbing into the canopy through any of a variety of plant modifications (*e.g*., thorns, tendrils, *etc*.). As with many other communities and strata, variation in the horizontal and vertical coverage in the vine layer depends upon the larger vegetation structure, successional stage, degree of disturbances from wind storms, floods, debris flows, *etc*., and various human activities. Vines also exhibit the phenomenon of "self-armoring" – i.e., the exposed edges of a forest fragment or in this case, the landward edge of a riparian forest, are completely overgrown by vines. The extensive vine growth effectively seals the forest from abiotic allogenic influences, such as wind speed, temperature, solar radiation, and creates an internal forest environment not necessarily hospitable to the native flora and fauna. The self-armoring also restricts or prohibits the movement of animals as well as plant propagules across the riparian corridor.

Within the reference domain, several exotic vine species (*e.g*., *Senecio mikanioides, Vinca major, Hedera helix*) are widespread, being able to grow under a large variety of site conditions, from full sun to dense shade. Consequently, several of the most pernicious weeds in the reference domain are vines, competing with native vine species (*e.g., Lonicera subspicata* vars.) for light, space, and nutrients.

Plant Community Functions
Plant Community Maintenance

Average Number of Vegetation Strata (V_{STRATA})

Multiple vegetation strata (*e.g.*, tree and shrub layers) often are good indicators of the development and maintenance of plant communities, habitat structure, and channel bank stability (Tilman 1994). For example, the number of strata can be correlated with the habitat structure and complexity necessary to support characteristic faunal assemblages (*e.g.*, those typical of the south coast of Santa Barbara County.) Similarly, the number and types of vegetation strata combine to provide the structural diversity of faunal habitat, as well as the types and quantity of food and cover resources available.

Percent cover class values for the four strata and the regeneration variable are averaged to provide a single measure of cover. This numeric value is then added to the variables for ratio of native to nonnative species tree basal area. These three values are considered equally important as three independent measures of plant community structure and function. The average of the measures is the single functional capacity index (FCI) for the plant community maintenance function.

Index of function:

$$[(V_{TREECC} + V_{SHRUBCC} + V_{VINECC} + V_{HERBCC} + V_{REGEN})/5 + V_{RATIO} + V_{STRATA} + V_{TREEBA}]4$$

Plant Community Functions

DETRITAL BIOMASS

Definition

Detrital Biomass is the process of production, accumulation, and dispersal of dead plant biomass of all sizes. Sources of detritus may be in channel, upslope in the riparian zone, or upgradient transport by flowing water. The emphasis in this HGM protocol is on the amount and distribution of standing and fallen woody debris.

Rationale for the Function

Woody debris contributes to the functioning of ecosystems by reducing erosion and helping build soils (McFee and Stone 1966). Decomposing detritus also provides wildlife habitat and serves as a store of nutrients and water (Franklin, Shugart, and Harmon 1987; Harmon *et al.* 1986; Thorp *et al.* 1985). Woody debris is a major source of energy and a major habitat for decomposers and other heterotrophs (Harmon *et al*. 1986; Seastedt, Reddy and Cline 1989). Coarse woody debris and debris dams (Smock, Metzler, and Gladden 1989) also play an important role in the dynamics of floodplain-stream ecosystems (Bilby 1981).

Fine woody detritus normally is associated with the forest floor detrital ecosystems, while coarse woody debris has both vertical and horizontal components typically at a larger scale. For example, standing dead trees (snags) may account for a large amount of coarse woody debris in forests and provide key habitat for many wide ranging species (Harmon and Hua 1991). Fallen trees and tree branches that come into contact with the soil surface undergo decomposition at a faster rate than standing trees. It is the decomposition process that ultimately converts wood into material that becomes incorporated into soil and recycles nutrients between living and dead biomass (Harmon *et al.* 1986).

One way of assessing this riverine ecosystem function is to evaluate the amount and distribution of woody debris relative to reference standards developed from sites that are mature and are likely to have stable accumulations of detritus. The amount of both fine and coarse woody debris can vary greatly as a result of storms, *(e.g.,* Hurricane Hugo's effect on the Congaree Swamp National Monument, a riverine floodplain forest in South Carolina (Putz and Sharitz 1991)).

Description of Variables Used to Assess Detrital Biomass

Basal area of standing dead trees (snags) (V_{SNAG})
In channel coarse woody debris (V_{INCWD})
Off channel coarse woody debris (V_{OFFCWD})
Decay class (V_{DECOMP})

Basal area of standing dead trees (snags) (V_{SNAG})

Standing dead trees (snags) are a normal component of forested floodplain and riparian wetlands. The density of standing dead trees provides information on the suitability of a site as animal habitat and whether or not a site is mature. A forested wetland may also contain more standing dead trees than the reference standard as a result of modifications to its hydrologic regime. For example, a restriction in the flow of a stream caused by the construction of a road crossing would lead to a die-off of less flood-tolerant trees on the affected floodplain. However, when establishing a reference domain or comparing assessment areas, one should also be aware of alternative explanations for site characteristics. For example, diseases (*e.g.*, Sudden oak death, Dutch elm disease) can be responsible for high mortality rates of trees in stream terrace and floodplain forests.

In channel coarse woody debris (V_{INCWD})

Down and dead trees, branches, and other forms of woody plant material within the active stream channel represent in-channel coarse woody debris (INCWD). This form of detrital biomass provides an important substrate for various phases of invertebrate life cycles (*e.g*., feeding, nesting, and rearing habitat), habitat for small vertebrates, and in particular, can serve as a refuge from high flows for animals during floods.

Off channel coarse woody debris (V_{OFFCWD})

Down and dead trees, branches, etc., on the floodplain, terrace and forest floor represent off-channel coarse woody debris (V_{OFFCWD}). Like in-channel coarse woody debris, off-channel woody debris provides an important substrate for most phases of invertebrate life cycles (*e.g*., feeding, nesting, and rearing habitat), habitat for small vertebrates (*e.g*., wood rats), and in particular, can serve as a refuge from high flows for animals during floods. The volume of fallen logs can be measured at an assessment site and compared to its reference standard. The length and diameter of downed wood can be measured rapidly using sampling and/or diameter tapes. Subsequently, the volume of fallen logs can be measured at an assessment site and compared to its reference standard.

Decay class (V_{DECOMP})

The presence of coarse woody debris in various stages of decay provides wildlife habitat for an array of different organisms, including bacteria, fungi, plants, various and poorly known protists, as well as a large diversity of animals, both vertebrates and invertebrates. Standard decay classes can be used to evaluate the range of decomposition within the ecosystem.

Plant Community Functions
Detrital Biomass

Variation Observed Within and Among Subclasses

For most of the variables that contribute to the two plant functions, there exists considerable variation in the reference data within and among all subclasses. For example, mean values for tree basal area are: high gradient 355.9 sq. ft./ac, medium gradient 257.2 sq. ft./acre, and low gradient 153.1 sq. ft./acre; for snag density, the mean values are: high gradient 58.0 stems/acre., medium gradient 121.9 stems/acre., and low gradient 42.9 stems/acre. However, while the statistics for the different subclasses vary, the variation as measured by the standard deviation equals or exceeds the mean value.

There are several possible explanations for this high degree of variation. In general, the vegetation within the reference domain is characterized by a large degree of intrinsic variation in such vegetation characteristics as dominance, species composition, and community structure that is direct consequence of a Mediterranean climate (Major 1988, Dallman 1998) and extremely active geology. In addition, anthropogenic modifications such as agriculture, nonnative introductions, grazing, and urbanization, have superimposed extrinsic variation upon the natural variation.

Every reference site exhibited some evidence of modification by humans. For example, in places where the vegetation was intact, water quality was degraded through the inadvertent inputs from leaking septic systems. Conversely, where the water quality and hydrology was intact, the vegetation was not, often evidenced by a predominance of a nonnative weeds in the understory strata. California has had a short, but intensive history of European settlement, and southern California in particular has undergone acute changes in its landscapes as a direct or indirect result of settlement and development. Ultimately, the variation observed within and among the reference sites suggests that variation is a natural part of the riverine ecosystems, that additional variation has been imposed upon these systems through the effects of European settlement, and that further reference sampling may be necessary to understand the significance of the range of variation observed.

Index of Function: $\{V_{SNAGS} + [(V_{OFFCWD} + V_{INCWD})/2] + V_{DECOMP}\}/3$

5.2.4 Faunal Support / Habitat Functions

SPATIAL STRUCTURE OF HABITATS

Definition

Spatial Structure of Habitats is the capacity of waters/wetlands to support faunal populations through the heterogeneity of structure of vegetative communities.

Rationale for the Function

Spatial structure of habitats evaluates the suitability of vegetative communities, micro- and macro-topography, and hydrologic conditions for sustaining characteristic animal populations in riverine ecosystems in southern Santa Barbara County. While all ecosystem attributes are important for the maintenance of faunal habitat integrity, the horizontal and vertical structural complexity of plant communities largely determines habitat quality for resident and non-residential animals. Generally, habitats with greater vegetative heterogeneity and structural complexity support more diverse faunal communities.

The heterogeneity of plant communities provides complex, three-dimensional structure in riparian zones for aquatic, semi-aquatic, and terrestrial vertebrates and invertebrates. Life history activities supported by habitat structure include predator escape, foraging, resting, reproduction, *etc*. Contiguous habitat structure provides potential movement zones for wide-ranging and migratory animals. Movement of faunal populations can potentially allow gene flow between separated populations, and/or avenues for progeny to exploit new areas. Habitat structure also regulates and moderates fluctuations in temperature and other aspects of the physical environment that limit or otherwise influence faunal populations.

Vegetation of mature, intact riverine ecosystems reflects the constraints imposed by environmental parameters (*e.g.,* climate, hydrologic regime, geomorphology, *etc*.), as well as the competitive interaction of plant populations. Plant communities have been shown to be an indicator of current and past disturbances within a riverine ecosystem (i.e. past and ongoing anthropogenic alterations in hydrogeomorphic conditions).

The goal of assessing the habitats spatial structure is to evaluate the structural complexity of a riverine ecosystem. This function is meant to be used as part of a rapid wetland functional assessment technique. The function is not meant to replace more detailed procedures or long-term habitat studies. If intensive studies of wildlife and animal communities are needed and justified, the more time-consuming Habitat Evaluation Procedure (HEP) should be used (U.S. Fish and Wildlife Service 1980).

Faunal Support / Habitat Functions
Spatial Structure of Habitats

Variables Used to Assess Spatial Structure of Habitats

Animal Sign (V_{ASIGN})
Buffer Contiguity ($V_{BUFFCONT}$)
Buffer Condition ($V_{BUFFCOND}$)
Buffer Width ($V_{BUFFWIDTH}$)

Animal Sign (V_{ASIGN})

The strongest indication that a wetland possesses adequate spatial structure of habitats is evidence of use by animals (V_{ASIGN}). The prevalence of evidence for animal use is characteristic of a healthy system. Unfortunately, the amount of evidence for animal use at any given site is controlled by a large number of factors, including the time of day, season, or even year of the site assessment. Due to these difficulties in accurate determination of animal use within a PAA, the number of different animal groups (*i.e*., mammals, birds, fish, reptiles, and amphibians) was used as a general indicator. Similar rapid assessments have been shown to be useful scoping tools for various planning and regulatory purposes (HEP manual).

Buffer Contiguity, Condition, and Width ($V_{BUFFCONT}$) ($V_{BUFFCOND}$) ($V_{BUFFWIDTH}$)

Contiguous native plant communities, supported by regulatory riparian buffers, represent a primary level of habitat connection between an assessment area and its surroundings. Buffers have been shown to support the maintenance of native plant communities, and thus provide the horizonal and vertical structural complexity that largely determines habitat quality for resident and non-residential animals. Uninterrupted riparian buffers can also provide corridors necessary for animal movement and migration in and out of waters/wetlands ecosystems. This movement between different habitats and/or landscape positions can allow genetic interaction between otherwise isolated populations, and recolonization of waters/wetlands where local plant or animal populations have perished due to adverse environmental conditions or predation. The integrity of these corridors may be disturbed through human-induced perturbations that can interrupt, remove, and/or reduce the width of the regulatory riparian buffers.

Faunal Support / Habitat Functions
Spatial Structure of Habitats

Shade (V_{SHADE})

The presence of vegetative overhang over an active stream channel can be an important habitat component to aquatic, semi-aquatic, and terrestrial animals. Vegetative overhang has been documented to provide the necessary cover and/or habitat conditions to aquatic and semi-aquatic animals for protection from larger predators. For example, an essential component to trout habitat is the overhanging vegetation; it is important to the maintenance of dissolved oxygen, and provides thermal regulation as well as protective cover. Semi-aquatic amphibians, such as the California newt, require vegetative overhang for protection on land as well as in the water during all stages of their life cycle. Larger terrestrial animals also require vegetative overhang that provides cover for escape, thermal regulation, reproduction, as well as feeding opportunities.

Residual Pools ($V_{RESIDPOOL}$)

The presence of residual pools in an assessment area is an indicator of potential fish and/or amphibian habitat. Residual pools can provide cover for both fish and/or amphibians from potential predators, as well as provide cover for thermal regulation, reproduction, etc. In the Low gradient subclass, access to intact residual pools in transitional areas where brackish and fresh water coalesce is critical for anadromous and catadromous species that need time to adjust to physiological (osmotic) stresses associated with making the transition from salt to fresh water. California newts, during their adult stages, use residual pools in the Medium and High gradient subclasses not only for escape from terrestrial predators but also for laying eggs in a well protected, thermally regulated stretch of water. Birds are known to use residual pools for regular feeding throughout the reference domain. In addition, wide ranging carnivores such as bears or mountain lions use residual pools as sources of water, and for thermal, resting, and escape cover.

Snag (V_{SNAG})

Standing dead trees (snags) are a normal component of the structural complexity of forested floodplains and riparian wetlands. The density of standing dead trees provides information on the suitability of a site as animal habitat and whether or not a site is mature. In terms of faunal support/habitat, snags primary importance is for avian habitat; both resident and migratory. For example, the importance of snags to woodpecker foraging is well documented. In addition, limbs of large snags provide resting, perching, feeding, and nesting sites for large birds, particularly raptors (*e.g.,* owls, eagles, etc.). While we have emphasized the importance of snags to avian habitat, snags can also be shown to be an important habitat component to small mammals, reptiles, and amphibians.

Faunal Support / Habitat Functions
Spatial Structure of Habitats

Variables Used to Assess Spatial Structure of Habitats, ***continued***

Strata (V_{STRATA})

Mature riverine ecosystems are usually vertically stratified, possessing equal to or greater than three vegetative strata in a mature forested riverine ecosystem. The number of strata can be correlated with the habitat structure and complexity necessary to support characteristic faunal assemblages. Heterogeneity in plant communities, and thus structural complexity, are known to affect faunal populations at different spatial scales. Differences in structure between sites likely represents differences in animal composition. Generally, the Author's argue that the more spatially stratified communities often contain more diverse faunal communities.

Index of Function:

$$((V_{ASIGN} + (V_{BUFFCOND} + V_{BUFFCONT} + V_{BUFFWIDTH})/3 + (V_{SHADE} + V_{RESIDPOOL} + V_{SNAG} + V_{STRATA})/4)\ /3$$

INTERSPERSION AND CONNECTIVITY OF HABITATS

Definition

Interspersion and Connectivity of Habitats refers to the capacity of waters/wetlands to allow aquatic, semi-aquatic, and terrestrial organisms to enter and leave a riverine ecosystem via large, contiguous habitat patches.

Rationale for the Function

Riverine ecosystems are used extensively by aquatic, semi-aquatic, and terrestrial organisms to complete portions of their life cycle that includes reproduction, feeding, growth, *etc*. Adequate habitat corridors are required for connecting riverine ecosystems to other portions of the landscape. For instance, riverine ecosystems are often used as corridors for movement of megafuana (*e.g*. Black bears, Mountain lions, *etc*.) from the Santa Ynez Mountains into lower landscape positions. Smaller, less mobile faunal species frequently require juxtaposition of habitat components or resources on scales consistent with their smaller home ranges. Habitat connections and the interspersion of resources contribute to the dispersal of plants and animals between habitats which allows animal populations access to the resources necessary to complete their life cycle.

Alteration of waters/wetlands and the isolation of animal populations by surrounding land uses that are incompatible with the requirements of the population, frequently accompanies increasing human population densities and economic activities. Studies of such habitat fragmentation show reduced faunal species richness as patch sizes decrease (Harris 1984). Connections between habitats help maintain higher animal and plant diversity across the landscape (Brinson *et al.* 1995). Interspersion and Connectivity thus characterizes waters/wetlands within their landscape settings.

Variables Used to Assess Interspersion and Connectivity of Habitats

Land Use ($V_{LANDUSE}$)
Patch number ($V_{PATCHNUMBER}$)
Patch Area ($V_{PATCHAREA}$)
Patch Contiguity ($V_{PATCHCONTIG}$)

Faunal Support / Habitat Functions
Interspersion and Connectivity of Habitats

Land Use ($V_{LANDUSE}$)

Surrounding land use represents the assessment of secondary connections between the PAA and its landscape context. Land uses occurring in the landscape surrounding a waters/wetlands largely determines the degree of alteration to native plant communities and the extent to which non-native analogs to native communities may exist within the surrounding landscape. Some land use activities are known to leave a portion of the native vegetation intact, allowing for the movement of animal populations in and out of stream ecosystem. However, other activities may replace native vegetation but still provide opportunities for animal movement and cover. Finally, the most intensive land uses remove or suppress all suitable cover for animal populations in and out of a stream ecosystem.

Patch number, Patch Area, and Patch Contiguity ($V_{PATCHNUMBER}$) ($V_{PATCHAREA}$) ($V_{PATCHCONTIG}$)

The three Patch variables all contribute to the assessment of primary and secondary connections between the PAA and the surrounding landscape. The three variables contribute to the measure of uninterrupted native plant communities that form corridors which are an essential component for the movement of faunal populations from the Santa Ynez Mountains into lower landscape positions. The integrity of these corridors may be disturbed by both natural and anthropogenic disturbances, which lead to the fragmentation of a landscape both within and around an assessment area. The fragmentation of a landscape and the edge to interior forest ratio can have great influence on the faunal assemblages within a riverine ecosystem. By increasing the edge to interior forest ratio, the large intact specific habitat patches are reduced removing the critical habitat for indicator species. Additionly, the increases in edge communities increases the rate of colonization of opportunist species that also assists in the reduction of specialist species through competition.

Index of Function: $[(V_{PATCHNUM} + V_{PATCHAREA} + V_{PATCHCONTIG})/3 + V_{LANDUSE}] /2$

DISTRIBUTION AND ABUNDANCE OF INVERTEBRATE TAXA

Definition

Distribution and Abundance of Invertebrate Taxa is defined as the capacity of a wetland to maintain characteristic density and spatial distribution of invertebrates (aquatic, semi-aquatic, and terrestrial).

Rationale for the Function

Invertebrates exploit almost every micro-habitat available in waters/ wetlands and may reach densities of thousands of individuals per square meter. Because invertebrates are so pervasive and partition habitats so finely, they are excellent indicators of ecosystem function.

Very little work has been done examining terrestrial invertebrate assemblages responses to perturbations within riparian areas. There is, however, a long history of impact assessment techniques using aquatic invertebrates. The richness of the taxa and the variety of tolerances within those taxa make rapid assessment using aquatic invertebrates difficult. Therefore, it is recommended that an established aquatic invertebrate analysis technique be used. One assessment technique for aquatic invertebrates is the Benthic Index of Biotic Integrity (B-IBI) (Kerans and Karr 1994). For the B-IBI to be applied to southern Santa Barbara County, invertebrate specialists must calibrate it to the reference domain.

If invertebrate specialists are not available, a rapid, albeit imprecise, direct measurement may be attained. Most of the Mayfly, Stonefly and Caddisfly taxa (Ephemeroptera, Plecoptera, Trichoptera, respectively) (EPT) are intolerant to perturbation (Hillsenhoff 1982, Kerans and Karr 1994, Plafkin *et al*. 1989). Therefore, a direct measurement of EPT richness could be made in the field and compared to reference standard conditions.

The Authors are unable to provide defined variables to contribute to an index of function due to the lack of invertebrate expertise in the field team, in addition to the limited scope of this project. However, this function has been included to signify the importance of invertebrate taxa in stream ecosystems and the potential to expand upon the current model provided in this *Draft Guidebook.*

Faunal Support / Habitat Functions

DISTRIBUTION AND ABUNDANCE OF VERTEBRATES

Definition

Distribution and Abundance of Vertebrates is defined as the capacity of waters/wetlands to maintain a density and spatial distribution of vertebrates (aquatic, semi-aquatic, and terrestrial.)

Rationale for the Function

Vertebrate distribution and abundance in any riverine ecosystem is extremely variable, and can change rapidly in space and time. For example, large mammalian species (*e.g*., Black bears, Mountain lion, *etc*.) require vast tracts of land in order to sustain a population. Therefore, in any given riparian system, especially in the lower gradient positions of Santa Barbara County, the level of use by these large mammals in an assessment area is episodic. On the other hand, many vertebrates are conspicuous users of waters/wetlands, and can have a strong influence on the dynamics of a riverine ecosystem.

The goal in assessing this function is to compare reference and assessment site functions with respect to species composition and structure of vertebrate species associated with a water/wetland and the presence of necessary habitats to support common (or rare) vertebrate faunal populations. Rapid, direct measurements of vertebrates are difficult to perform in the field. Direct sightings, as well as indirect indicators of animal use can both be used assess this function. The following are suggestions, given the expertise and scope of work, to accurately measure this function:
Perform complete surveys by vertebrate specialists and compare to reference standard conditions using similar indices. Reference local species lists for mammals, birds, fish, amphibians, and reptiles and compare to reference standard conditions using similar indices.

The Authors are unable to provide defined variables to contribute to an index of function due to the lack of vertebrate expertise in the field team, in addition to the limited scope of this project. However, this function has been included to signify the importance of vertebrate taxa in stream ecosystems and the potential to expand upon the current model provided in this *Draft Guidebook.*