

**A Classification Framework for  
Wetlands and Related Ecosystems in  
British Columbia:  
Third Approximation**

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## ABSTRACT

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Wetland and “riparian” ecosystems have ecological characteristics that distinguish them from terrestrial systems. They are affected by dynamic and temporally variable hydrology, typically occur as complexes of site types that act together as ecological units in the landscape, and interact closely through patterns of waterflow with adjacent ecosystems. While some aspects of terrestrial ecosystem classification can be applied, additional factors, which reflect these unique characteristics, must be included.

In this paper, we present a model that connects several extant classifications into a single framework. We propose a 3-component classification that uses “natural” ecological features, is multidisciplinary and hierarchical, and is compatible with the several widely used classifications. Primary sources of concepts and units are the Biogeoclimatic Ecosystem Classification, the Canadian Wetland Classification System, and Hydrogeomorphic Classification.

Distinction is made between classification of homogenous sites (Site Component) and classification of whole systems (Hydrogeomorphic classification). These two components can be integrated in a classification of ecosystem complexes (Mosaic Component). The framework has the following essential features.

1. A site classification that links the Biogeoclimatic ecosystem classification (BEC) and the Canadian Wetland Classification in a functional hierarchy of site potential. Concepts are extended to non-wetland ecosystems.
2. A modification of the edatopic grid of BEC to explain site factors important in wetlands
3. A hydrological/geomorphic landscape classification to provide a whole system context for description of landscape units based on hydrological systems and related geomorphic patterns
4. A method for classifying wetland and riparian areas that are predictably repeating complexes by integrating the site and hydrogeomorphic components

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## INTRODUCTION

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Wetlands and Riparian areas provide wildlife, fisheries, biodiversity, water quality and aesthetic values that are disproportionately large compared to their limited extent in the landscape (Gregory *et al.* 1991; Mitsch and Gosselink 1993; Pinay *et al.* 1990; Forman and Godron 1981; Malanson 1993). Recognition of the special nature of these habitats by researchers and managers of natural resources has led to the establishment of conservation legislation and regulations in many jurisdictions. In British Columbia, the Forest Practices Code provides special management protection of riparian and wetland ecosystems. Guidelines for riparian management are outlined in the Riparian Management Area Guidebook (RMAG; Ministry of Forests 1995) using an administratively and operationally simple classification system. However, the RMAG does little to address ecological differences among specific wetland and riparian types. Recognition of these differences is required to achieve “best management practice” of wetland and riparian areas or to be able to make informed interpretations for other tasks.

One of the most important tools for understanding ecosystems and applying ecosystem management principles is an ecologically based classification system. Classifications allow for the ordering, comparison, synthesis, mapping, and inventory of information and give resource workers a common language to communicate results (Lotspeich and Platts 1982). Biogeoclimatic ecosystem classification (BEC) has been widely and successfully applied to forested sites in B.C. (Pojar *et al.* 1987) and could be extended to wetland ecosystems (e.g. Steen and Roberts 1988). However, the application of BEC to wetland ecosystems presents some challenges because of several unique characteristics of wetlands:

- hydrology and hydrodynamics are not used in BEC but major site factors in wetlands (Mitsch and Gosselink 1993).;
- wetland and floodplain ecosystems are intimately connected to “external” landscape processes through hydrology (Naiman and Decamps 1990) and can only be understood within a larger, landscape context (Lotspeich 1980; Gregory *et al.* 1991; Malanson 1993; Mitsch and Gosselink 1993; Brinson 1993). BEC is a site classification and does not include landscape criterion in its framework; .and
- wetland and “riparian” ecosystems, as landscape features, are almost always complexes of associated ecosystems (rather than homogenous sites) that act together as an ecological landscape unit..

In recognition of these limitations, Kistritz and Porter (1993) reviewed existing wetland classification systems for possible use in British Columbia. Local (Runka and Lewis 1981; Moon and Selby 1982; Roberts 1984; Steen and Roberts 1988), provincial (Jeglum *et al.* 1974), national (National Wetlands Working Group 1993) and international (Dethier 1990; Cowardin *et al.* 1979) wetland classifications were evaluated. A synthesis of several systems was recommended. A discussion paper outlining a proposed classification scheme was produced and circulated for review among members of the B.C. Wetlands Working Group (Kistritz and Porter 1993). The consensus from this review was that further work was required on the classification scheme and efforts should be made to complete a classification of wetland and riparian ecosystems in one system.

The Wetland and Riparian Ecosystem Classification (WREC) framework presented here is a hierarchical 3-component classification using concepts and units from several existing classification schemes. Distinction is made between classification of homogenous sites (Site Component) and classification of whole systems (Hydrogeomorphic classification).

The site component is a functional hierarchy that uses the Site Association of BEC (Pojar *et al.* 1987) as a fundamental unit grouped into broader Classes following a modified interpretation of

the Canadian Wetland Classification System (Warner and Rubec, 1997). A separate hydrogeomorphic component describes landscape patterns and connectivity. This component is based in part upon the Hydrogeomorphic systems (Brinson 1993), and Classification of Wetlands and Deepwater Habitats in the United States (Cowardin et al. 1979).

These two components may be integrated into a Mosaic component at several functional scales that describes repeatable combinations of related ecosystems in the context of predictable hydrogeomorphic patterns. The component has similarities to the Ecosite concept of Racey and others (1996) and the Form/Subform of the Canadian Wetland Classification System (Warner and Rubec 1997).

Description of specific units of the classification are not presented here for the sake of clarity. A full description of units can be found in MacKenzie (2001 in prep)

## 1 RATIONALE AND OBJECTIVES

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We have followed several guiding principles in constructing this classification framework:

1. The classification will be based on “natural” features, which reflect environmental processes and not arbitrary management objectives;
2. It should take a comprehensive or multidisciplinary approach to reflect the ecotonal nature of these ecosystems;
3. Units of the classification will reflect an appropriate range of spatial and functional scales for use in research and management. To this end the classification should be hierarchical and descriptive at multiple scales of resolution;
4. It must be compatible with currently used classification schemes.
5. It should provide clear criterion for distinguishing units

## 2 CONCEPTS AND TERMINOLOGY

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### *Wetland*

Wetlands are ecotones between terrestrial and freshwater ecosystems. They occur on semi-terrestrial to semi-aquatic sites where the water table is at, near, or above the soil surface. Soils are water-saturated for a sufficient length of time that excess water and resulting low soil oxygen levels are principal determinants of vegetation and soils development.

### *Riparian Areas and Flood ecosystems*

The term “Riparian” is defined or applied in the literature in several contradictory ways. To avoid the confusion associated with this term, WREC does not use it to describe any formal unit of the classification. We apply it in general discussion simply as a term of adjacency. “Riparian” does not imply any specific ecological feature of a site other than it occurs next to a water body. By this definition, any type of ecosystem may be riparian. For those ecosystems that are ecologically distinct because of flooding, erosion/sedimentation, or sub-irrigation from an adjacent water body, WREC uses the term Flood Ecosystem.

### *Hydrophytes*

Hydrophytes are plants adapted to growing in waterlogged soils. Excessive water and the low rate at which oxygen diffuses under these conditions leads to a complex of critical conditions that require specialized adaptations (Daubenmire 1959). Obligate hydrophytes are restricted to wetlands and aquatic environments and their presence at a site usually indicates a wetland environment. Facultative hydrophytes occur most commonly in wetlands but also appear in some upland sites.

### *Classification versus description*

Site description and ecosystem classification are different but complimentary processes. Site description produces a simple list of biotic and abiotic features for an ecosystem. No two ecosystems will have the exact same list of site characteristics and each site could be considered unique. However, to apply knowledge gained on one site more widely, groups of sites with similar ecological function must be recognized. Ecosystem classification distills the variability among sites into recognizable groups based on a few ecologically important factors. These fundamental properties feature prominently within the formal classification; other descriptive attributes are used as supporting information. Standard methods for description of wetlands are outlined in Province of BC (1998) and MacKenzie (in prep).

### *Succession, Climax, and Site potential*

Site potential is a central concept in BEC. It defines the potential of a given location to support a specific climax plant association. Climax communities of forested ecosystems are indicated when the forest canopy contains the same tree species as those in the regenerating understory. In late successional stands, the climax forest type can be predicted from the understory tree species, shrubs and herbs. In non-forested wetlands, this convenient method is not available. While the composition of the organic layers in wetlands can give some indication of preceding communities, future trends in succession are more difficult to predict than in upland communities. More importantly, unlike upland sites where site potential is relatively constant, wetlands and “riparian” ecosystems are dynamic entities that respond rapidly to changing hydrological regimes. Changes in water table regime, progressive accretion of flood plain sediments, or paludification may change site potential of wetland and flood plain locations over time. Therefore, the concepts of climax and site potential in wetland and flood plain sites must be viewed as more fluid than in uplands.

## **3 GENERAL CHARACTERISTICS OF THE WETLAND CLASSIFICATION**

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One of the challenges faced when developing wetland and riparian classification is choosing variables and assigning priority to them in the classification. A balance between physical and biological aspects of systems features prominently in this exercise. Less commonly addressed but often more important is clarification of the functional and/or spatial scale to which the classification applies. We have addressed these issues by adopting a hierarchical component approach that separates the classification of homogenous sites within wetland and riparian areas from a classification of entire wetlands. The classification is comprised of three components: Site, Hydrogeomorphic, and Mosaic. Users of the framework can choose the component(s) that are suitable for each project. Furthermore, each component is functionally or spatially hierarchical so that an appropriate scale can be applied on a case basis.

### *A Component System*

To maintain greater consistency in classification structure and avoid the issues of assigning classification priority to different aspects of the ecosystem, we have applied a classification with Site and Hydrogeomorphic components. The Hydrogeomorphic component emphasizes hydrological processes and geomorphic forms for an entire wetland. The Site component emphasizes the environmental site potential and concurrent biological community for homogeneous sites within a wetland. This site classification uses hydrology as a descriptor of site potential but separates this site hydrology description from description of the hydrological context of the wetland as a whole.

### *Spatial and functional hierarchy*

Hierarchical classifications have three valuable attributes:

- group units such that description of higher levels reduces the number of variables needed to describe more specific lower units;
- allow integration of information presented at different spatial or functional scales;
- permit the selection of an appropriate scale of resolution for different management and research problems (Godfrey 1977).

Classifications designed at one spatial scale have limited application at other levels of detail (Allen and Hoekstra 1992).

The Site component of WREC is a functional hierarchy in that it describes the same site at several different levels of specificity. The Hydrogeomorphic component has functional and spatial

components; the System and Subsystem are functionally related while the Feature is a spatially finer unit than the Element.

### *Integration*

Classification by separate physical and biological components allows greater consistency and ease of definition. However, an integrated classification (such as BEC) that brings the physical and biological description together has advantages. It produces a single ecological unit that more clearly defines site potential and ecological functioning and allows for broader application.

Existing site classifications, such as BEC, are used for broad to fine scale mapping and planning. For ecosystems that are homogenous over relatively large areas, this is possible. However, ecosystems such as wetlands and riparian areas usually occur as complexes of ecosystems even at fine scales making application of BEC problematic. Frequently, these naturally complex ecosystems occur as repeatable patterns of associated communities that reflect underlying hydrological gradients or geomorphologic processes (Brinson 1993; Hupp and Osterkamp 1985). Understanding these ecosystems requires placing them within a larger landscape framework (Bedford 1996). For these types of situations, a higher spatial scale of integration is required for description and mapping. We introduce the Mosaic unit to fulfill this need.

### *Inclusion of other classifications*

Integration of existing classifications of streams, wetlands, and terrestrial communities into WREC is desirable (Bunnell *et al.* 1995; Kistritz and Porter 1993). WREC has adopted or modified units from other landscape and wetland classifications to capitalize on previous theoretical and practical work. Units from several sources have been placed within a single architecture (Table 1).

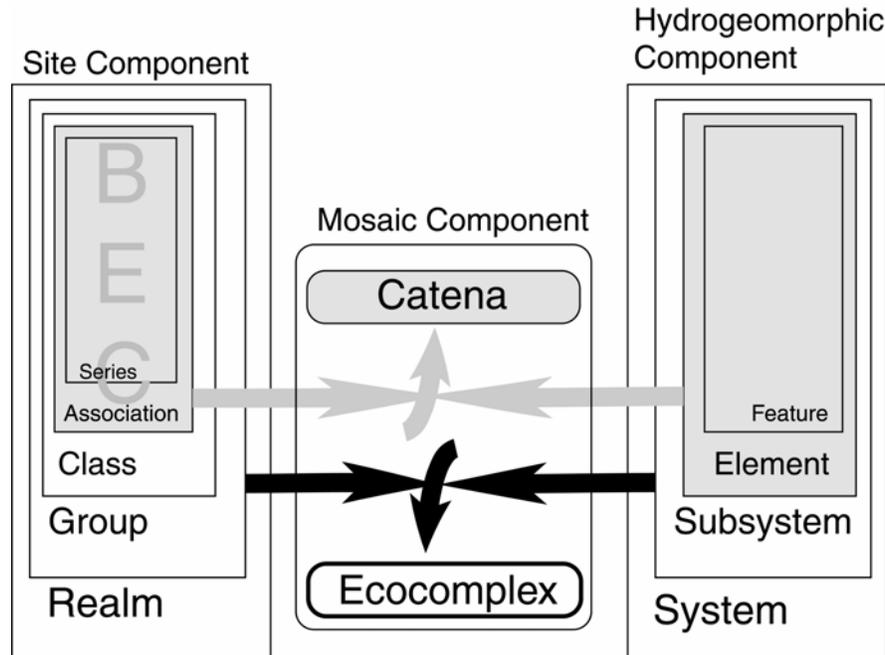
**Table 1 Literature sources and names of units applied in WREC**

<b>Classification Source</b>	<b>Source Unit(s)</b>	<b>Equivalent WREC Unit(s)</b>
Biogeoclimatic Ecosystem Classification (Pojar et al. 1987)	Site Association/Site Series	Site Association/Site Series
Canadian Wetland Classification System (Warner and Rubec 1997)	Wetland Class	Wetland Classes. Concept transferred to other Ecosystem Realms
""	Wetland Form and Subform	Some equivalent to Landscape associations
Preliminary Wetland Managers Manual (Runka and Lewis 1981)	Shrub-Carr and Graminoid meadow wetland classes	Transition Classes
""		Pond Elements
US Classification of Wetlands and Deep Water Habitats (Cowardin et al. 1979)	System	Hydrogeomorphic System
Classification of Fluvial Landforms (Kellerhals et al. 1976; Rosgen 1994).	Stream Reaches and units	Fluvial Subsystems, Elements, Features
Fish and Fish habitat Inventory (RIC 1997)	Lake classification	Lacustrine Subsystems, Elements
Peatland Development classification (Ivanov in Ingram 1983)	Development pattern	Palustrine Subsystems

#### **4 FRAMEWORK SUMMARY**

Some major features of the classification include:

1. A site classification integrating the BEC site association with the CWCS Class and expansion of Class concepts to non-wetland ecosystems
2. A modification of the BEC edatopic grid to portray additional site factors important in wetlands.
3. A hydrological/geomorphological landscape classification for describing the environmental context for wetland complexes using existing concepts where possible.
4. A method for classifying wetland and riparian areas that are predictably repeating complexes of site units using the site and hydrogeomorphic components.



**Figure 1. The WREC classification framework showing units of site and hydrogeomorphic component used to create mosaic units**

#### *Site component*

The Site component is a functional hierarchy where the specific site units of Biogeoclimatic Ecosystem Classification (BEC) are successively grouped on the basis of more general ecological similarities. The site series and site association units of BEC describe site potential on ecologically homogeneous areas based on climate, soils, and vegetation climax communities. The “Class” concept of the Canadian Wetland Classification system is used in WREC as broader description of site potential; in the process clarifying the scale at which this unit is applied. Additional higher level units (Group and Realm) formalize currently used, but imprecisely defined, terminology. These higher units accent similarities in basic underlying processes and functions between ecosystems not reflected in vegetation and place wetlands in a broader ecological context.

#### *Hydrogeomorphic component*

The concept of hydrogeomorphic classification has been developed by Brinson (1993). This approach characterizes wetlands by geomorphic setting, water source, and hydrodynamics. The Hydrogeomorphic hierarchy of WREC defines broad hydrological systems which imply dominant hydrological properties and the geomorphic patterns that arise within them. The units are intended to be remotely interpreted and do not rely on site hydrology measurements. At more specific levels repeating hydrologic / geomorphic patterns that arise from and reflect specific system characteristics are described.

#### *The Mosaic Component*

Wetlands and riparian areas typically occur as complexes of associated sites in the landscape. By combining the site and hydrogeomorphic components repeating complexes of sites can be described. The Mosaic component provides a means by which repeating patterns of ecosystem sites can be described as a single unit for the purposes of mapping, inventory, and other landscape scale study. The component has two levels. The Ecocomplex uses the System/Subsystem and Group/Class levels of the two components to describe whole wetlands.

The Catena describes a sequence of Site Associations in relation to hydrogeomorphic Elements or Features in a Wetland.

## 5 SITE CLASSIFICATION

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The approach taken by WREC is to use the strong theoretical and practical background of the Biogeoclimatic ecosystem classification (Pojar et al. 1987) to define basic working units. The site series of BEC is defined by climax plant communities on ecologically equivalent sites within a climatic subzone/variant. Site associations are groups of similar site series that cross subzone/variant boundaries. WREC uses this Site Association unit as the basic working unit for the classification. Site associations are grouped into Classes, Classes into Groups, and Groups into Realms (Figure 1). These higher units of the ecosystem component are defined by environmental states characterized by specific guilds of biota rather than species groups. Functional units such as these accentuate similarities in basic underlying processes and functions between ecosystems not reflected in vegetation and provides a means of relating ecosystems at several scales.

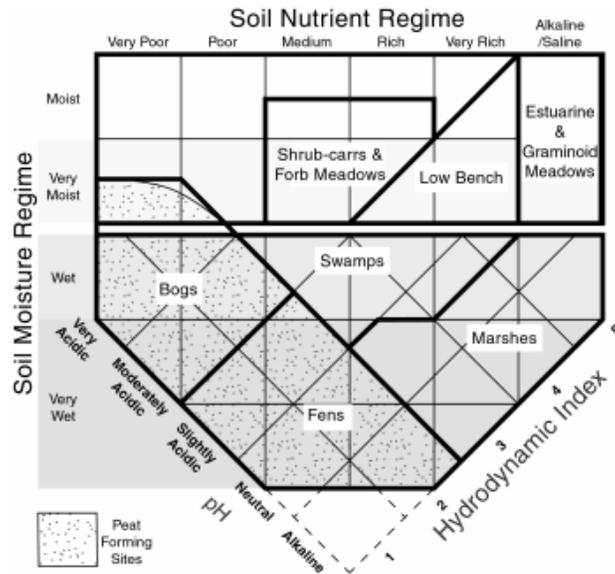
### *Site Series/ Association*

*The site association defines all sites capable of supporting a similar plant association at climax.*

Vegetation classification using a Braun-Blaunquet approach produces units with characteristic indicator species groups (Mueller-Dombois and Ellenberg 1974). When these species groups represent climax communities, they are said to reflect site potential and are used to define the site series within biogeoclimatic subzones and variants (Pojar et al. 1987)..

### *Wetland Edatopic (hydroedatopic) Grid*

In BEC, the edatopic grid is used as a conceptual model for visually representing the relationships among forested ecosystems along soil moisture and nutrient gradients (Pojar et al. 1987). However, these two factors alone do not adequately characterize sites that occur in the wet and very wet portions of the grid (i.e. peatland and mineral wetlands). WREC presents a modified edatopic grid (Figure 3) that places the subhydric and hydric portions of the grid within a tangent matrix of water acidity/alkalinity and a hydrodynamic index (HI). This model is based on concepts outlined in Vitt (1994).



**Figure 2. Distribution of wetland classes on a modified edatopic (hydroedatopic) grid using watertable acidity/alkalinity and hydrodynamic index as tangent environmental axes for wet and very wet sites. Note: Aquatic wetlands do not fit this model.**

1. **Actual Soil Moisture Regime (ASMR)** is the average amount of soil water annually available for evapotranspiration by vascular plants over several years (Pojar et al. 1987). There are nine moisture categories from excessively dry to very wet. Wetland and wetland-related ecosystems are only found on wet to very wet sites. The wetland edatopic grid is therefore limited to this range. The definition for soil moisture categories used in the guide are defined in Pojar and others (1987).
2. **Soil Nutrient Regime (SNR)** is the amount of essential soil nutrients (primarily N and P) that are available to vascular plants over a period of several years (Pojar et al. 1987). Six SNR classes are recognized from very poor to very rich. Wetland and wetland-related ecosystems can occur throughout the range and an additional sixth class has been added to accommodate alkaline/saline habitats.
3. **Acidity/alkalinity** is a correlate to availability of base cations ( $Mg^{++}$ ,  $Ca^{++}$ , etc) and affects nutrient availability. Five categories are recognized from very acidic to alkaline. Sites with *very acid* (<4.5 pH) or *moderately acid* (4.5 to 5.5 pH) soil water are dominated by *Sphagnum* mosses. *Slightly acid* (5.5 to 6.5 pH), *neutral* (6.5 to 7.4 pH) and *alkaline* (>7.4 pH) sites are dominated by "brown mosses" on peatland sites.
4. **Hydrodynamic index (HI)** is a qualitative assessment of the magnitude of lateral ground water flow or vertical water-table fluctuation; both factors that affect nutrient availability through input of dissolved nutrients and improved soil aeration. The scale ranges from 1 to 5. HI 1 and 2 sites have stagnant to very gradually moving soil water and accumulate peat; HI 5 sites have highly dynamic surface water or significant periods of substrate exposure and aeration. Sites with hydrodynamic values greater than 2 have lateral groundwater movement and significant vertical water table fluctuation, poorly developed moss layers, and little or no peat accumulation.

#### **Site Class**

*The site class describes sites with similar basic underlying environmental attributes that support similar characteristic species guilds at climax.*

A national wetland classification is widely used in Canada (Warner and Rubec 1997). The wetland Class defined in this Canadian Wetland Classification System (CWCS) defines broad ecosystem types by general environment and vegetation features. The concepts applied to the Class are similar in nature to the Site Association of BEC in that they describe environmental states characterized by certain guilds of biota. However, the Class definitions of the CWCS are intentionally non-specific to allow wide application in diverse ecological regions. For example, hydric mineral soils, high nutrient availability and emergent grass-like vegetation characterize the Marsh Class. Because of the relative simplicity of the features used at the Class level, this unit is valuable for multidisciplinary uses. Only rudimentary knowledge is necessary for identification and interpretation. Therefore, it facilitates communication of results between “specialists” and resource workers. The Class is also useful in regional comparisons where species assemblages differ.

The Canadian Wetland Classification System (Warner and Rubec 1997) uses the “Class” concept to describe both sites and whole wetland systems. This confounds scale and makes it difficult to attach clear definitions to units. To clarify this scale issue, WREC defines the Class as a functional **site unit** for grouping together Site Associations with broadly similar vegetation physiognomy (or species guild), hydrology, and water quality.

**Table 2. Wetland and related ecosystems defined in WREC.**

<b>Realm</b>	<b>Group</b>	<b>Class</b>
Wetland	Peatland	Bog Fen
	Mineral	Swamp Marsh
	Aquatic	Shallow water
Terrestrial	Flood	High bench Mid bench Low bench Active channel
	Transition	Shrub-carr Graminoid Meadow Forb meadow
Estuarine	Low	Estuarine Tidal Flat
	High	Estuarine Marsh Estuarine Meadow Estuarine Swamp

### **Group**

*The Group designates a broad association of functionally similar ecosystems based on a dominant cluster of ecologically relevant environmental features.*

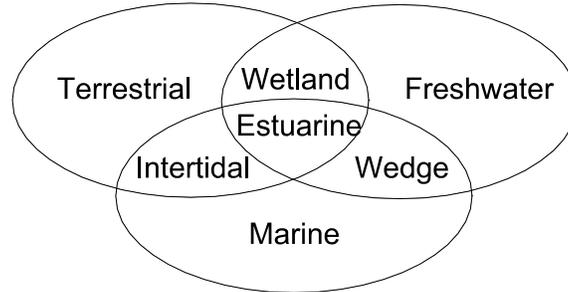
A single dominant environmental factor or attribute reflecting a constellation of factors that influence ecosystem structure are used to differentiate between Groups. For example, within the Wetland Realm, the Peatland Group is distinguished from the Mineral Group based on the presence of deep fibric or mesic peat accumulations that indicate low decomposition rates, lower available nutrients and near-permanent saturation. The Flood Group of the Terrestrial Realm includes those ecosystems that are strongly influenced by periodic/seasonal flooding events common in riparian situations.

### **Realm**

*The Realm delineates major biotic types that reflect gross differences in water abundance, quality, and source*

The aim of the WREC project is to describe not only true wetlands, but also ecosystems associated with flood plains and transitional sites. To place wetlands and non-wetlands within the same classification architecture, additional levels of generalization within a hierarchy are required.

The Realm is the broadest level of distinction within the ecosystem component and it delineates major biotic types that reflect gross differences in water abundance, quality, and source. The model of the ecosystem realms (Figure 4) provides a framework for defining broad ecological types, clarifying the relationships between them, and promoting a coordinated approach to classification initiatives (Fraser et al. unpub.)



**Figure 3 The Ecosystem Realms**

There are three primary realms (Terrestrial, Freshwater, and Marine) and 4 secondary realms where the primary realms intersect (Wetland, Estuarine, Intertidal, and Wedge). The secondary realms exhibit unique characteristics in addition to features that are common to the related primary realms.

***Management interpretation from Ecosystem site classification***

Site associations classify site potential using communities of vegetation that occur at climax. These units are specific and require a level of botanical knowledge to be applied successfully. For some applications such as coarse scale mapping, initial habitat evaluation, setting up comparative research trials, and communicating results to users with little botanical knowledge however, units that group ecosystems with similar ecological function and structure are preferred. The Class and Group of the ecosystem component provide a consistent means of grouping site associations with similar underlying features, emphasize similarities among ecosystems, and therefore may clarify relationships. Some possible uses of each of the ecosystem levels is outline in Table 3

**Table 3 Interpretive characteristics for different levels of site classification for an example ecosystem (Drummond's Willow - Bluejoint)**

<b>Ecosystem Unit</b>	<b>Possible uses of the unit</b>	<b>Example of Unit</b>	<b>Characteristics and interpretation for example</b>
<b>Realm</b>	Identification of appropriate classification structure to use, identifies important environmental factors and broad biotic groups.	<i>Terrestrial</i>	Site is likely dominated by upland vascular plants typical in the climatic region and is on relatively well-drained soils.
<b>Group</b>	Identification of ecosystems with a common dominant ecological factor that will influence management and research. Blocking variable in research design and management interpretations	<i>Flood</i>	Site is riparian and has flood potential. Community dominated by non-wetland plants tolerant of flood events. Possible high wildlife capability and productivity sites.
<b>Class</b>	Broad management interpretations based on known characteristics. Prioritizing sites for habitat protection. Extension and communication of results to non-technical users.	<i>Low Bench</i>	Shrub community with a sparse understory occurring directly adjacent to flowing water. The site experiences long periods of flooding, with pronounced erosion and deposition; but is not a wetland. Commercial tree growth not possible. Prolonged spring flood render sites unsuitable for ground-nesters and burrowers.
<b>Association</b>	Identification of rare or sensitive ecosystems Identification of "natural plant community" Specific wildlife or fisheries habitat capability interpretation Specific management interpretations based on known controlling site factors	<i>Drummond's Willow - Bluejoint</i>	Tall shrub community of Drummond's willow, and erosion resistant graminoids and annuals. Site likely on sandy/silty levees beside slow moving, interior streams.

## 6 HYDROGEOMORPHIC CLASSIFICATION

A hydrogeomorphic classification has not been widely used in B.C. but is the central concept of wetland identification and management in the US (Cowardin et al. 1976; Brinson 1993). This classification approach recognizes some of the fundamental features that control the ecosystem structure and composition on a site. Units of this classification rely on knowledge of landscape properties and not specific hydrological variables and are therefore relatively easy to assess (Bedford 1996).

The hydrogeomorphic component of WREC emphasizes a landscape approach to wetland classification using hydrology and geomorphology. Profiling the hydrogeomorphic environment of wetland ecosystems is critical for understanding ecosystem function and maintenance requirements and provides a means of relating environmental controls with biological communities (Brinson 1993; Bedford 1996).

Maxwell and others (1995) identify the need to select fundamental factors in hydrogeomorphic classification which:

- dominate ecological processes;
- show similarities in pattern;
- are causal;
- covary with other important ecological attributes; and
- reflect hierarchical constraints.

Brinson (1993) suggests that geomorphic setting, water source, and hydrodynamics are the three most important criteria.

The Hydrogeomorphic component of WREC proposes a modified spatial hierarchy to describe the landscape and geomorphologic features and processes that influence wetland and riparian ecosystems (Fig. 1). This system first places sites within broad hydrological context that implies a water source and pattern of water flow. Geomorphic groups that further define the nature of hydrological flow within each system are then outlined. Finally, a specific geomorphic pattern that arises from hydrological factors is defined. These levels of the hydrogeomorphic component meet the criteria outlined above.

### ***System***

*The hydrogeomorphic System describes the landscape position of the ecosystem in relation to hydrological factors.*

The System defines a contiguous area that shares the influence of similar dominant water source(s) and hydrological processes, and is characterized by particular geomorphologic forms. Six Systems are recognized in WREC: Upland, Palustrine, Lacustrine, Fluvial, Estuary, and Marine. The System differs from other levels of the hydrogeomorphic component by identifying hydrological processes instead of actual geomorphic features. Furthermore, it differs from the site component by describing all sites within the contiguous influence of the hydrological system.

**Table 4 Characteristics of the Hydrogeomorphic Systems**

System	Topographic position	Primary Water source	System Hydrology
<b>Palustrine</b>	Small (< 1ha) or shallow lakes (> 75% area < 2m deep), basins, and seepage slopes	Groundwater, Precipitation, or Stream and Lake flooding	Low energy flooding or groundwater fed. Vertical fluctuation.
<b>Lacustrine</b>	Large (> 1ha) and deep water bodies	Lake flooding	Subject to flooding by wave action; fed by circulating lake waters. Bi-directional and vertical fluctuation
<b>Fluvial</b>	Adjacent to creeks, streams, or rivers.	Stream flooding	Subject to annual stream flooding and erosion/deposition forces; stream fed. Unidirectional flow.
<b>Estuary</b>	Confluence of freshwater inflow into marine environment	Stream and ocean flooding	Subject to diurnal or periodic flooding and brackish water. Vertical and bi-directional
<b>Marine</b>	Ocean	Ocean flooding	Intertidal and subtidal locations
<b>Upland</b>	Any	Precipitation and groundwater	Soil moisture not in excess.

***Subsystem***

*The subsystem specifies broad geomorphic groups within a System that reflect important broad hydrological properties of the ecosystem*

The Subsystem joins geomorphic elements together that have broadly similar hydrological processes. It provides a background for understanding general hydrological regime of a landscape unit. For Fluvial Systems, the Subsystems define river bottom reaches that are erosional (headwater), intermediate (Transport), or depositional (Alluvial) (Kellerhals et al. 1976). For Palustrine systems, basin form, slope, presence of open water and linkage are used to define groups (Ivanov ; Runka and Lewis 1981).

**Table 5 Subsystems of selected Systems**

System	SubSystem
Palustrine	Basin Slope Pond
Fluvial	Alluvial Transport Headwater
Lake	Anthropogenic Littoral Deepwater

***Element (Forms?)***

*The Element is a complex geomorphological landform reflecting glacial deposition patterns, active hydrological processes or underlying hydrological gradients.*

Several existing classifications and concepts operate at the spatial scale of the Element. The terrain classification (Howes and Kenk 1988) is applicable at these scales as is the 'reach' in stream classification, which is comprised of a complex of ecosystems and landforms that reflect common fluvial processes. Repeatable spatial patterns within systems are described by the

Element. This includes characteristic zonation, stream/flood plain patterns, or landforms that occur in the landscape. In reality, vegetation may be used to provide clues to hydrogeomorphic patterns and features (Brinson 1993). Therefore, for basin wetlands, observed vegetation zonation patterns, which reflect underlying soils or hydrological gradient may be used to describe the hydrogeomorphic element.

**Table 6 Some example Elements of selected Subsystems**

<b>SubSystem</b>	<b>Element</b>
Pond (Palustrine)	Closed
	Overflow
	Linked
	Terminal
Basin (Palustrine)	Domed
	String
Alluvial (Fluvial)	Typic (infill)
	Anastamosing
	Delta
	Tortuous meander
Estuary	Fjord
	Fjard
	Delta
	Strand

### ***Feature***

*The feature is a geomorphological unit that describes a simple landform or position within a larger complex landform (Element).*

The feature describes the spatial “pieces” of a complex site and allows location description for where specific communities occur with a mosaic.

**Table 7 Example Features typical of some Elements**

<b>Element</b>	<b>Feature</b>
Palustrine	Shore
	Water-track
	Pool
Fluvial	Levee
	Pool
	Lateral bar
Lacustrine	Bay
	Beach
	Littoral zone

### ***Management interpretations from Hydrogeomorphic Classification***

The hydrogeomorphic component provides a broader perspective on wetland functioning. For some purposes, such as monitoring water quality or fisheries value, this component of the classification framework will be more important to assess and monitor than a biological component. “Best management practice” may rely on hydrogeomorphic criteria for some functions of wetlands (Brinson 1993). A hydrogeomorphic classification can predict local stream response to disturbance, vegetation patterns, aquatic habitat quality and distribution (Frissel et al. 1986, Maxwell et al. 1995). Table 4 outlines some example of interpretations made using the different levels of the hydrogeomorphic classification.

**Table 8 Some characteristics and interpretation made for different levels of the Hydrogeomorphic Component**

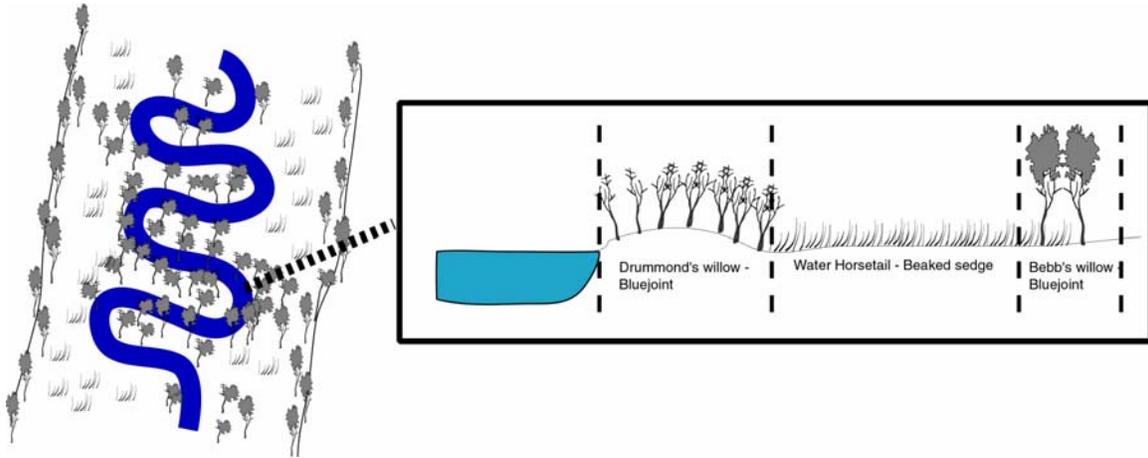
<b>Hydrogeomorphic Unit</b>	<b>Possible uses of unit</b>	<b>Example of Unit</b>	<b>Characteristics and interpretations for example</b>
<b>System</b>	Identification of landscape units with simple broad hydrological function and water source. Broad interpretations based on hydrological regime.	<i>Fluvial</i>	Site is associated with a river or stream.  Special riparian management practices. Possible high fisheries and wildlife habitat values.
<b>Subsystem</b>	Recognition of geomorphic forms that represent major System divisions in relation to patterns of water flow. More specific interpretations on flood potential. Broad habitat values	<i>Alluvial</i>	Site is of low gradient and is a sediment deposition area. Likely with a well developed flood plain.  Flooding of riparian zone likely. Special development guidelines and wildlife values
<b>Element</b>	Repeating spatial patterns of sites related to specific hydrological factors. Specific management interpretations based on hydrological characteristics.  Mapping and inventory unit. Specific habitat values.	<i>Tortuous Meander</i>	Site very low gradient and has pronounced meanders and low width to depth ratio. May have oxbows, back channels, and back levee depressions.  System stable under normal conditions but sensitive to disturbance. Vegetation control of channel high and erosion potential high.
<b>Feature</b>	Understanding site specific hydrology and other environmental conditions that affect vegetation communities	<i>Levee</i>	Raised ridge of fluvium usually directly adjacent to slow moving sediment laden stream coarse. Often downstream of higher gradient reaches.  Specific environmental conditions for vegetation communities.

## **7 CLASSIFICATION OF WETLAND AND RIPARIAN COMPLEXES**

Wetland and riparian ecosystems are generally heterogeneous at moderate scales. These patterns are the result of internal gradients reflecting relationships to water sources and subsurface topography in Palustrine and Lacustrine systems and geomorphic flood patterns in Fluvial and Estuary systems. This is in contrast to most upland ecosystems that are relatively homogenous over large areas. For sites where the underlying geomorphic features are more dynamic or heterogeneous, the Site Series or Association is less useful for mapping and description. Broader, integrative ecological units that recognize repeating complexes of ecosystems in the landscape provide a prospective that enhances understanding of these ecosystems and subsequent management applications.

The Mosaic component presented in this paper provides a method for connecting the repeating geomorphic patterns of Fluvial systems or the hydrological gradient of Palustrine systems to their associated biological communities. The result are units that encapsulate most of the important traits of wetland and riparian sites. We propose two units – the Ecocomplex and the Catena-- to

blend the hydrogeomorphic classification with site classification to produce predictive landscape units. These units describe different functional and spatial scales.



**Figure 4 Diagram of Fluvial Low bench/Marsh Meander Stream EcoComplex consisting primarily of a Drummond's willow / Water horsetail Catena**

#### *Catena*

*The Catena describes sequences of site associations that occur together along the environmental gradient of a hydrogeomorphic element or feature.*

Ecosystems may repeatedly occur adjacent to, or in association with, other related ecosystems. Often this occurs because the environmental gradients within a type of hydrogeomorphic unit are consistent. A spatial gradation of water table depth or water flow is common in many wetlands and ecosystems are arranged predictably along this gradient. This predictable linear arrangement of ecosystems along an environmental gradient is known as a Catena (Forman 1995). In WREC, the Catena uses BEC site units combined with hydrogeomorphic features or elements to create units.

The Ecosite (Racey et al. 1996) is a similar unit to the Catena. It is an ecological mapping unit used in Ontario that describes common vegetation associations occurring on soil types and is proposed as a mapping unit.

#### *EcoComplex*

*The EcoComplex describes reoccurring spatial patterns of Classes or Groups within a Hydrogeomorphic system*

The EcoComplex is broader or coarser ecological unit than the Catena describing a spatial arrangement of clusters of ecosystems on predictably heterogeneous environments. Instead of describing specific site association relationships, the EcoComplex describes the physical form of an entire wetland and the broad ecosystem Classes or Groups that predominate in the System. The Wetland Form of the CWCS (Warner and Rubec 1997) describes some units that would be considered EcoComplexes in WREC (e.g. Basin Bog, String Fen etc.)

## **8 SOME APPLICATIONS OF WREC**

The initiative to create a classification of wetlands and riparian areas in B.C. was initiated to produce a system for addressing a wide range of management and research questions. By providing a framework that places existing and new classifications into a single architecture, WREC allows organization of current ecological knowledge about provincial wetland and related

ecosystems. This hierarchical system encourages study and use of appropriate ecological scale in management and research (Allen and Hoekstra 1995). The separation of the classification into site and “landscape” components that rely on biological and hydrological factors also allows users to select an approach that is most suitable to the needs of the project.

There are several applications for this classification:

1. Direct management interpretations for units of the ecosystem site and hydrogeomorphic components
2. Mapping and inventory
3. Hydrogeomorphic profiles
4. Predicting ecosystem change

#### *Inventory and Mapping: the Ecocomplex*

At scales broader than 1:10 000, simple homogenous wetland and riparian ecosystems are difficult to distinguish. The Ecocomplex and Catena units are introduced to accommodate formal description of repeating site patterns.

The Ecocomplex is a much-generalized unit suitable for rapid assessment and characterization of landscape units from aerial photos and for broad scale inventory. The Catena is more specific and requires a more intimate knowledge of local ecosystems and site relationships.

The Mosaic component is designed to fulfill a similar function to the broad habitat units outlined in the context of the Terrestrial Ecosystem Mapping (TEM) methodology used in British Columbia (RIC 1997?). Several levels of description are proposed that allow for the appropriate level of detail to be used based on need, knowledge, or cost.

#### *Hydrogeomorphic profiles*

Brinson and Rheinhardt (1996) have promoted the use of reference wetlands for monitoring and researching potential impacts and mitigation. These reference sites are described using a hydrogeomorphic profile for “fully functioning” environments and provides the basic template to which potentially impacted wetlands can be compared. The hydrogeomorphic component of WREC coupled with descriptive environmental variables incorporated into field sampling methods (Ministry of Forests 1997) provide the features with which groups of wetlands with functional similarities can be joined. These functional groups can then be used for monitoring, directing research (by providing a blocking variable) and suggest types of wetlands and riparian areas that should be treated as similar for management prescriptions.

#### *Predicting ecosystem change*

The conceptual model of the hydroedatopic grid can be used to predict changes to community structure with modifications to environmental parameters. Wetlands communities can change rapidly from one type to another under changing hydrological regime. The edatopic grid diagrams four major environmental gradients, which allows the user to predict community change. This method is a conceptual model and its application should be qualified with additional information.

Wetlands are commonly affected by natural and human caused hydrological changes. These include:

- water table stabilization (weirs, beaver dams, paludification);
- water table elevation (weirs, beaver dams, blocked culverts at road crossings);
- improved drainage/water table depression (ditching, removal of beaver dams, water extraction for irrigation, drought);
- nutrient inputs (sewage and stormwater inflow, agricultural run-off, livestock use);
- modified ground water flow (redirected inflow channel, floodplain realignment).

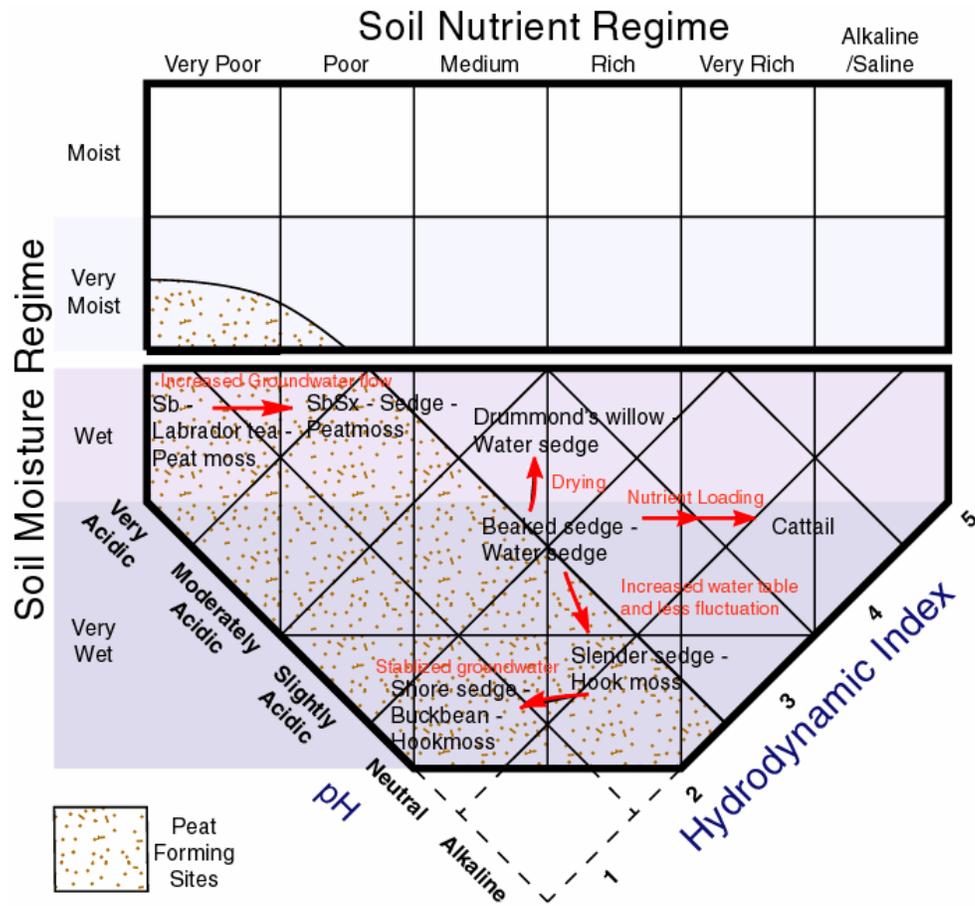


Figure 5 Application of the hydroedatopic grid for predicting shift in site potential caused by hydrological changes.

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