Reference Standards and Project Performance Standards for the Establishment of Depressional Flow-Through Wetlands in the Puget Lowlands of Western Washington

January 16, 1998

Amanda L. Azous, Mason B. Bowles, Klaus O. Richter

This report was funded in part through a cooperative agreement with the National Oceanic and Atmospheric Administration.

Reference Standards and Project Performance Standards for the Establishment of Depressional Flow-Through Wetlands in the Puget Lowlands of Western Washington

by:

Amanda L. Azous
Environmental Consulting
Resource Management
P.O. Box 530
Olga, WA 98279

Mason B. Bowles
King County Department of Natural Resources
201 South Jackson Street, Suite 510
Seattle, WA 98104

Klaus O. Richter
King County Department of Natural Resources
201 South Jackson Street, Suite 600
Seattle, WA 98104

This document should be cited as:

Azous, A.L, Bowles, M.B., Richter, K.O. 1998. Reference Standards and Project Performance Standards for the Establishment of Depressional Flow-Through Wetlands in the Puget Lowlands of Western Washington. King County Department of Development and Environmental Services, Renton, WA.

Acknowledgments

This project was funded by a Coastal Zone Management Grant through the Washington Sate Department of Ecology. Many individuals assisted in the development of this document. We would like to thank Jennifer Thomas for reviewing technical aspects of many of the variables along with Tina Miller, who also reviewed early drafts of the manuscript. Jeff Burkey and Rhett Jackson, Ph.D., significantly contributed to the development and review of the section discussing Reference Standards for Hydrologic Functions. Dr. Tom Hruby reviewed an early draft of this report and provided guidance on nomenclature and identified "red flags."

Forward

The standards in this document are for use in establishing depressional flow-through wetlands in the Puget Lowlands. They represent a "first cut" at developing "standardized" guidelines for planning, designing, and evaluating compensatory wetland mitigation projects. As such they should be used by wetland professionals familiar with designing and monitoring the performance of created or restored wetlands.

These standards have been developed primarily for use in developing regional mitigation banks. They provide the optimum requirements for buffer size and legal protection, hydrologic modeling, minimum wetland size, and vegetation characteristics, among others. These standards may also be applied to other types of compensatory wetland mitigation projects with appropriate scaling of the standards.

The project performance standards, in particular, could be made more robust with scientifically-based (i.e., with controls) monitoring programs at created or restored wetlands. Regularly monitored information from these sites could be used to establish ecological trends for the establishment of wetland characteristics including, but not limited to: hydrology and hydric soil formation, plant survivorship, cover and strata establishment; coarse woody debris and snag recruitment, and wildlife usage.

Ideally, these standards would be established as moving statistics that would be revised with inputs from additional field surveys, experimental studies, and other data sources. The Puget Sound Wetland Stormwater Management Research Program database is a unique 10-year long data source that could serve as a repository for such future field research data in order to track long-term changes in wetlands. Moreover the program could serve in providing guidelines for future long-term research.

Table of Contents

1. Introduction

This document provides reference standards for planning and designing the creation, restoration, and enhancement of functions associated with depressional flow-through wetlands. In order to evaluate the development of these functions, project performance standards have also been developed. These are used as benchmarks of performance against which to measure the development of ecological characteristics associated with specific wetland functions. These reference standards are based on a hydrogeomorphic-based approach to wetland characterization and assessment initially developed by Brinson et. al. (1993) and adapted for regional use by Hruby et al. (1997). These standards were developed using data acquired through the Puget Sound Wetland Stormwater Management Research Program (Azous and Horner 1997), this effort (Azous et. al. 1997b [this report]), and several other sources as referenced

The hydrogeomorphic (HGM) method provides a comprehensive, and systematic framework for classifying wetlands and assessing their functions (Smith et. al. 1995) based on regional, hydrologic and geomorphic properties. The use of the hydrogeomorphic method (i.e., HGM), is consistent with federal, state and local efforts to improve the evaluation and replacement of wetlands based on the ecological functions they perform. The HGM has been identified by the federal government (Clinton Administration Wetland Policy 1993) and the State of Washington (Hruby et. al.1997) as the preferred approach to assessing wetland functions.

Policies for “no net loss” of wetland acreage or functions have been established at federal, state, and local levels. To enforce these policies jurisdictions require wetland mitigation, including impact avoidance, minimization, rectification, and compensation. Compensatory mitigation, involving wetland restoration, creation, or enhancement, is required for replacing wetland area and functions when development impacts to wetlands are unavoidable. Verifying that compensatory mitigation wetlands are replacing lost wetland functions has, however, proven extremely difficult. This has attributable to an absence of a) an agreed upon list of important wetland functions, b) standardized methods for assessing the level of performance of respective functions provided by wetlands, c) criteria or specifications for designing compensatory mitigation projects to replace lost functions, and d) scientifically based performance standards that can be monitored to assess the development of functions.

These inadequacies are being resolved in large part due to the widespread adoption of HGM as a unifying approach to wetland classification and assessment. For example, using the national HGM methods as a model, scientists of the Washington State Wetland Function Assessment Program (WSWFAP) are preparing a function assessment method applicable to western Washington. This regional effort is identifying wetland functions and providing standardized methods for assessing the variables that enable high performance of identified functions.

This document augments this effort by providing, where possible, empirically derived wetland reference standards, and from these, suggesting project performance standards that can be applied to evaluate projects using this regional approach. Reference standards represent the range of values (i.e., highest to lowest) for different ecological variables as determined by surveys of reference wetlands. Reference standards are used for planning and as design criteria for wetland mitigation projects.

Project performance standards are measurable benchmarks used to evaluate the development of ecological characteristics associated with specific wetland functions. They are used as a standard of comparison, against which measurements of mitigation project characteristics can be evaluated. Project performance standards may, in some instances, also serve as design specifications for planning compensatory mitigation projects to replace lost functions. We believe that project performance standards should be used as a tool and not as a rigid standard. Project monitoring data should be thoroughly evaluated against project performance standards as well as project objectives and goals before a final determination of project success or failure is made.

We derive both our reference and project performance standards from the analysis of long-term field studies of 19 (i.e., reference) wetlands in the Puget Sound Lowlands (Azous and Horner 1997), special studies of 6 wetlands, four of which were heavily impacted by urbanization (Azous et al. 1997) and our own function and variable-specific surveys and data analysis of hydrology, snags and other wetland characteristics in 4 of these original 19 wetlands (Azous et. al. 1997b [this study]), and suggestions from the literature including the Washington State Department of Ecology (Washington State Department of Ecology 1993), the Oregon State Study (Roth et. al. 1993), and the Federal Highway Administration Wetland Evaluation (i.e., WET) method (Adamus 1987).

We suggest the reader of this report consult these original sources for description of the sites, survey methods, data analysis and conclusions. The data provided by these sources preceded HGM; therefore, the reference domain used (19-24 wetlands and the information provided in these efforts) may not represent the diversity of the optimal number of wetlands (50 or more) for rigorous extrapolative capabilities. Consequently, some reference standards based on fewer wetlands than others will exhibit lower confidence. Nevertheless, the wetlands within the selected reference domain do contain wetlands in the same regional setting and are within hydrogeomorphic characteristics (depressional flow-through) describe in this report and represent the best available, empirically-derived data set and information from which to recommend compensatory mitigation performance standards at this time. Finally, because our data sources primarily derived their data from surveys of regional depressional flow-through wetlands, our resulting reference standards are applicable only to the siting and design of compensatory wetland mitigation projects where depressional flow-through wetland functions will be lost as a result of land use development.

2. Approaches to Wetland Function Replacement

This section provides the regulatory and technical context for compensatory wetland mitigation. It includes a review of compensatory wetland mitigation, methods of evaluating the performance of compensatory mitigation projects, and a review of wetland function assessment methods.

2.1. Compensating for Wetland Losses

Various Federal, State and local laws, regulations, and policies govern the protection of wetlands and include provisions requiring compensation for wetland losses. Wetland mitigation requirements are established as an integral part of wetland protection. These laws direct the proponents of development projects with anticipated wetland impacts to demonstrate that mitigation sequencing has occurred. This requires the proponent to document that efforts have been made to avoid, minimize, rectify, reduce, or compensate for any wetland impacts. Wetland replacement is required only when the wetland impact or loss is unavoidable. Such replacement is known as compensatory mitigation and may involve any combination of wetland restoration, creation, or enhancement activity, as well as the use of wetland mitigation banks.

Wetland mitigation banks are a form of regional compensatory mitigation. Through banking, relatively large areas of wetlands are restored, created, or enhanced for the express purpose of providing off-site mitigation for more than one wetlands impact. Multiple, small mitigation projects are consolidated into a large-scale wetland complex, resulting in economies of scale in planning, implementation, and maintenance. Wetland mitigation banking typically requires compensation in advance of impacts, thereby reducing temporal losses associated with compensatory mitigation that is implemented after the impact has occurred.

The King County Wetland Mitigation Banking Program (King County 1997) serves both public agencies and private development interests that have real constraints to providing on-site compensatory wetland mitigation. An Interagency Oversight Committee made up of federal, state, tribal and local agencies reviews and approves mitigation banking projects, participation, and the release of banking credits. The King County program is available to both private and public sector entities that satisfy all policy and technical guidelines presented in the Banking Program. These include the use of reference standards for planning and designing wetland mitigation banks, and the use of project performance standards for evaluating the development of ecological characteristics associated with specific wetland functions

Compensatory wetland mitigation typically involves replacing some combination of lost wetland area, structure, or function (Richter et. al.1997). Regulatory guidelines for wetland compensation in King County, Washington, require that replacement wetlands provide equivalent or greater abiotic and biotic functions such as flood control and wildlife habitat (King County 1993). These guidelines have not, however, been well implemented because of deficiencies in both wetland function assessment methods and wetland function design criteria.

More specifically, these deficiencies include: a) lack of standardized methods for identifying the functions, and assessing the level of performance of functions in wetlands; and b) the absence of criteria or specifications for designing compensatory mitigation projects so as to specifically replace lost functions. As a result of these problems, wetland mitigation designers and regulators have accepted the use of lesser standards (e.g., replacement of acres impacted) for identifying the extent of impact and for evaluating the success of mitigation projects.

Most mitigation projects are limited to replacing lost wetland area. This is the simplest, quickest and cheapest, and currently is the most commonly used method of wetland mitigation. These areal requirements are usually established by regulatory replacement ratios (i.e.: 2:1 impact: replacement).   Site planning and design specification are usually based on best professional judgment (BPJ). Refinements in the method may require that specific types of Cowardin (1979) habitats be established as part of the total wetland acreage replacement.

In addition to replacing wetland area, wetland mitigation projects may be also be designed to provide elements of wetland structure. In these cases functions are not specifically identified but rather assumed to occur when structural characteristics are provided. The West Eugene Wetlands Plan (City of Eugene 1993) used design guidelines to provide structural specifications that include grading, plant/water depths, plant species and planting techniques. Site selection criteria and hydrology were highly proscribed, limiting mitigation projects to specific sub-basin locations. These site selection and design standards were obtained through extensive monitoring of structural conditions at reference wetlands within the sub-basin. Such structure-based approaches are particularly appropriate when compensatory mitigation is limited to rare or unique wetland habitats that are regionally well defined and which may be poorly represented in the literature. In these instances ecological function models are not pre-requisites to establishing successful mitigation projects. Absent information on the functions provided by such wetlands, structure-based mitigation offers a valid strategy for replicating wetland functions by association, based on measurements of similar reference wetlands.

2.2. Evaluating Mitigation Project Success

Evaluations of compensatory wetland mitigation projects (Kusler and Kentula 1990, Kentula 1992, Redmond 1992, Wilson and Mitsch 1996) have revealed that the success of compensatory mitigation projects is generally poor. Problems include noncompliance with permit conditions, poor documentation of wetland functions lost or replaced, and out-of kind replacement of hydrogeomorphic types, hydroperiods, plant communities, and habitat functions. A common problem for wetland regulators evaluating the success of mitigation projects is that mitigation plans rarely include performance standards for gauging the success of the mitigation project (Elliot, 1985; Castelle et. al. 1992).

Mitigation designers are, for the most part, reluctant to identify specific measures of success for evaluating the performance of mitigation projects. Because mitigation projects are generally designed using BPJ, there is no scientific basis for establishing measures of success. As a result, concern exists among wetland ecologists, designers and engineers that measures of success based on BPJ will not be attainable, resulting in expensive and time consuming

contingencies for project proponents. Wetland regulators, for their part, rarely require mitigation designers to identify and replace lost functions due to an absence of science-based (and therefore legally defensible) guidelines for evaluating project performance.

Due to the absence of science-based standards for measuring mitigation project success or functions, mitigation project success is generally based on measures of plant survivorship; the attainment of crude, “green is good” standards. These require that mitigation projects satisfy minimum vegetation diversity and cover requirements within a set number of years. At a slightly more rigorous level, mitigation projects are delineated at the end of the monitoring period to determine if the required wetland replacement area has been provided. In either case, once the requirements are met, wetlands are assumed to be functioning in all aspects.

2.3. Measures of Success

Improving the performance of wetland mitigation projects requires measures of success that can be impartially and quantitatively evaluated to determine if the wetland characteristics associated with wetland functions are developing as planned. Measures of success are measurable benchmarks used to evaluate the development of ecological characteristics associated with mitigation projects. Such measures may be variously identified as standards of success (Ossinger 1996), project targets (Brinson1995), performance criteria (City of Eugene 1993), or performance standards (Hruby 1994).

Measures of success may be based on some combination of: 1) values reported in the literature; 2) values obtained from wetland mitigation projects; 3) values obtained from a wetland that will be altered; and 4) values obtained from reference standards. Literature-based information can offer scientifically verified values for comparing measured variables (Richter 1997) from mitigation projects. For the most part though, literature-based standards are incomplete because studies are based on analysis of wetland habitats that do not share functions similar to regional wetlands. These shortcomings will gradually diminish as the body of research and publication surrounding the development of methods to assess wetland functions increases. Values obtained from monitoring mitigation projects or wetlands that are subject to alteration are also directly relevant to the establishment of project performance standards. Older mitigation projects can serve, to some degree, as reference wetlands to evaluate trends in the attainment of structure and functions in similar, newer mitigation wetland projects. The utility of this approach is, however, limited because mitigation project monitoring results are not widely published and available.

Typically, measures of success have been limited to wetland structural characteristics which can be rapidly assessed. These structural characteristics are generally limited to some combination of measures of the diversity, distribution, or abundance (cover) of vegetation. Using such measures wetland mitigation project performance is typically evaluated using plant survivorship standards. Plants serve as relatively reliable indicators of soil moisture regimes, form the basis of the food chain, may be rapidly measured and analyzed to determine their diversity, density, distribution, and dominance, and are used to define wetland community types. For example, performance criteria for the West Eugene Wetlands Plan (City of Eugene 1993) limited overall

project standards of success to the establishment of: a) a minimum number of desired native plant species; b) minimum percent cover of native graminoids; and c) maximum percent cover of non-native species.

Measures of success are particularly useful due to limitations inherent in the use of function assessments. Function assessments may not be capable of measuring changes in levels of performance of functions due to: a) short regulatory monitoring timelines (i.e.: 5 years); or b) an absence of suitable "rapid" assessment indicators (i.e.: capable of classifying hydroperiods in one field visit). Function assessments are, moreover, not useful for identifying deficiencies in project design or construction which inhibit the development of wetland functions (i.e.: insufficient hydrology, excessive infiltration).

Optimally, mitigation projects designed to provide specific functions will be evaluated using a combination of measures of success and function assessments. Measures of success provide an intermediary step in evaluating the progress of compensatory mitigation projects that complements the use of function assessments. To work in tandem, however, both steps must be based on, and share the use of similar reference wetlands.

2.4. Function Assessments

Evaluating wetland mitigation project success may be performed using function assessments when methods are developed that can measure changes in the performance of specific functions. This approach has been identified as the preferred option for evaluating the performance of wetland mitigation banks (Federal Register 1995). Function assessments are methods for measuring the capacity of a wetland to perform a function. Development of function assessment methods for evaluating the loss and replacement of wetland functions has been driven by the Clean Water Act (33 U.S.C. 1344). This law, which has played such a significant role in the development of wetland regulations, requires a public interest review that includes an assessment of the impact of proposed development projects on wetland functions.

Wetland functions are the physical, chemical, and biological processes or attributes performed by wetlands. They are defined by Smith (1995) as the "normal or characteristic activities that take place in wetland ecosystems or simply the things wetlands do." All functions are not, however, provided equally by all wetlands. For example, riverine or lakeshore wetlands have the opportunity to provide rearing habitat for salmonids; this opportunity is generally absent from headwater depressional wetlands. Conversely, headwater depressional wetlands generally perform flood storage and water quality functions that contribute to the downstream health of riverine and lakeshore wetlands.

Wetland functions are the product of complex interactions between various ecological characteristics, termed variables. Variables represent the environmental characteristics that are considered to be important in the performance of a function (Hruby et al 1997). A wetland function assessment typically identifies functions potentially being performed in a wetland by measuring these *Variables*. For example, amphibian habitat functions are provided by wetlands as the product of ecological variables that include water level fluctuation (which defines

breeding territory), and the presence of thin-stemmed emergent plants (used for egg oviposition). When functions cannot be directly and rapidly measured (e.g.: amphibian breeding territory) the variables which contribute to the performance of a function are measured (e.g.: *Fluctuation* and *Thin-stemmed emergents*). In some instances indicators are used to determine the presence or performance of a variable (e.g.: drift lines are used as indicators of the height of surface water inundation for the variable *Fluctuation*).

The wetland characteristics used to assess functions are selected from a wide variety of sources. These may include literature-based sources, as well as inferred and anecdotal information on wetlands located in many different regions. All function assessment methods are generally limited to measuring the potential for functions to be occurring in a wetland. While hydrologic functions can be directly measured, other functions are presumed to occur through the presence of specific wetland structural characteristics (i.e., the variables). In other words, wetland structure is used as an indicator of potential wetland function.

Function assessments are used to evaluate the functions associated with wetlands subject to impacts from development activities so that they can be replaced. Relatively well known function assessment methods include the Reppert (Reppert 1979) and WET (Adamus 1987) function assessment methods. These approaches have not, however, not been accepted for use in evaluating the performance of mitigation projects. These two approaches are based on comprehensive, but generalized foundations of ecological data. They rely on standards obtained through literature reviews, anecdotal information, or inference.

The promise of function assessment methods like HGM is that they can be used to measure changes in performance, allowing for comparative analysis between mitigation sites and reference wetlands. For example, assessments of variables associated with amphibian habitat functions might reveal that thin-stemmed emergent plant cover is low relative to reference wetlands. These results might contribute to lowering the overall evaluation of the level of performance of amphibian habitat functions. Such resolution in the measurement of changes in the performance of functions has, however, not yet been delivered by function assessment methods. Most methods do not provide the resolution necessary for measuring changes in functions.

The hydrogeomorphic (HGM) approach (Smith et al. 1995) used to develop reference standards (Azous et al. 1997b [this report]) assesses wetland functions by: (1) classifying wetlands by hydrologic and geomorphic properties into a regional subclass (Brinson 1993); (2) identifying functions and variables that are associated with the regional wetland subclass; and (3) evaluating reference wetlands to establish function indices for gauging relative levels of functioning. In this way HGM function assessments are “referenced” to regional characteristics because the level of performance of a function is indexed relative to the reference wetlands. The HGM function assessment method allows for changes in potential function to be measured over time.

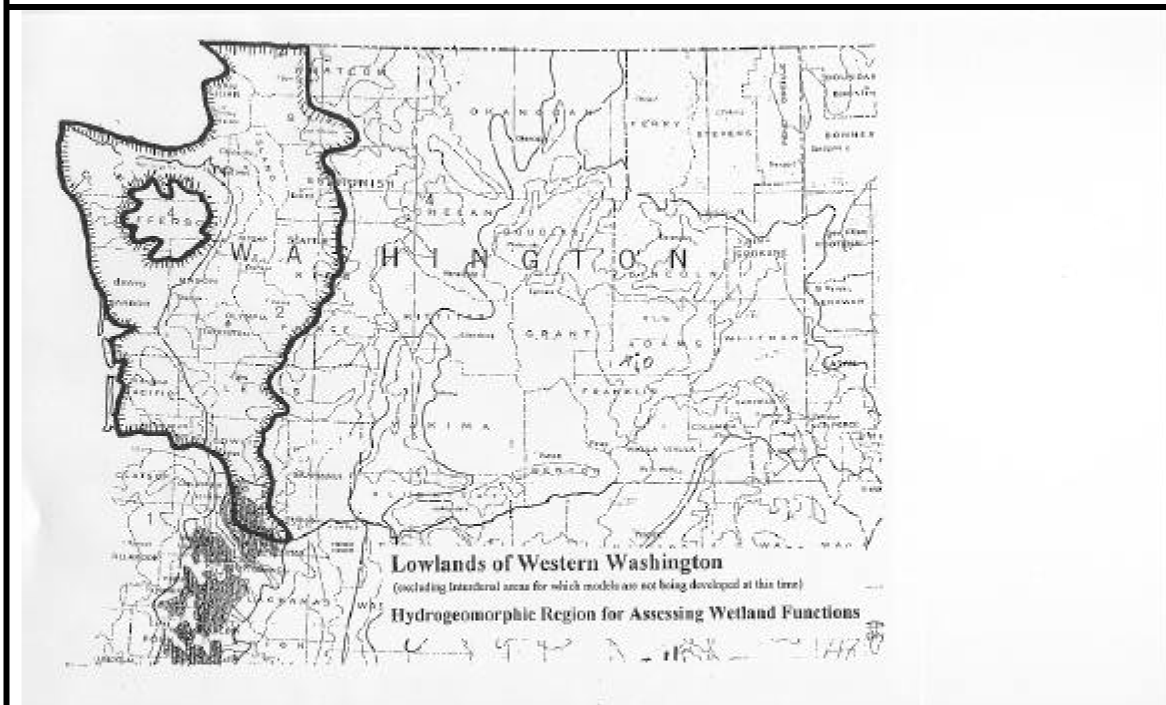
The HGM approach to assessing wetland functions promises to remedy many of the problems inherent in the use of comprehensive, but generalized function assessment methods. The HGM

approach was used to determine (Reinhardt et. al.1997) pine flat wetland reference standards, assess function performance in wetlands subject to development impacts, and determine (hypothetically), function performance in replacement mitigation wetlands. Regionally, the Washington State Wetland Function Assessment Program (WSWFAP) (Hruby 1997) is an effort to develop rapid, scientifically valid methods of assessing wetland functions that is based on HGM and combined elements of the IVA method.

3. Establishing Reference Standards and Project Performance Standards

This section describes the rationale and approach used to generate reference standards and project performance standards. The Reference Domain, Reference Wetlands, Reference Standard Sites, and the HGM subclass are identified and described. Methods for identifying and selecting functions and variables for use in developing reference standards are provided.

Figure 1. Puget Lowlands of Western Washington (Hruby et al. 1997).



3.1. The Reference Domain

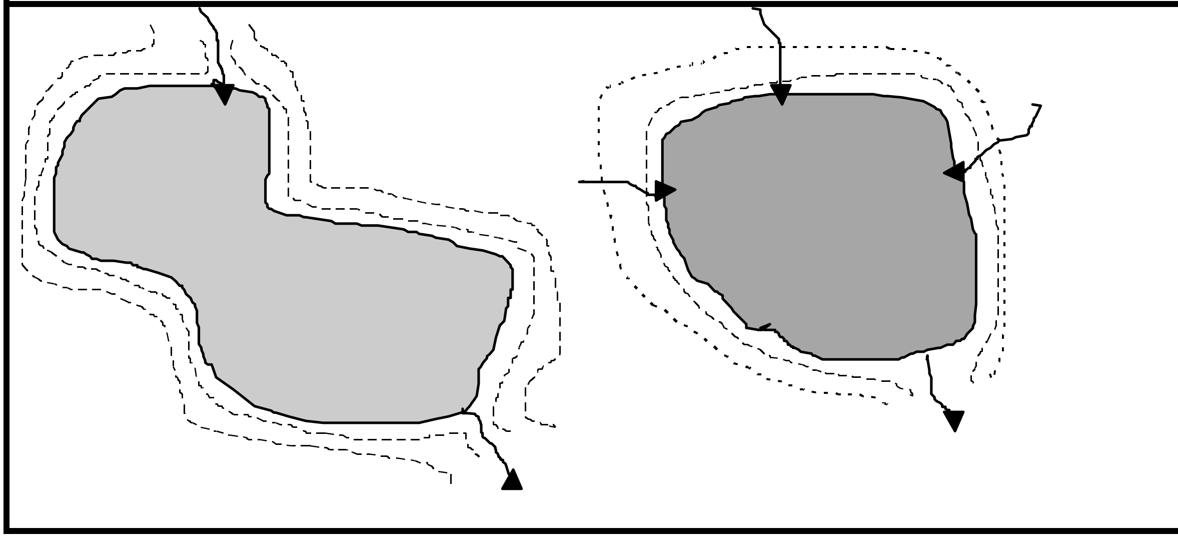
The reference domain is defined as “all wetlands within a defined geographic region that belong to a single hydrogeomorphic subclass.” (Brinson 1995). The reference domain was limited by the scope of the PSWSRMP to the Puget Lowlands (Omernik 1986) (Figure 1). This reference domain is characterized by distinct climatic and geological conditions. These include a mesic climatic regime with relatively uniform precipitation during the well defined wet season that occurs from October to March. A dry season with more variable and intense precipitation occurs between April and September. As a consequence of the Vashon glaciation, many soils within the Puget Lowlands are underlain by a dense glacial till. This till layer limits infiltration and provides an ideal substrate for the development of wetland characteristics when suitable topographic (i.e.: depressional) conditions exist. Because of the moist mesic climatic regime depressional wetlands are readily established when topographic conditions exist or are altered in soils with glacial till layers.

3.2. Depressional Flow-Through Wetlands

Depressional flow-through wetlands (see Figure 2) are the dominant wetlands class found in the Puget Lowlands. Analysis of wetlands studied by the PSWSMRP revealed that all 19 study wetlands satisfied the definition of depressional flow-through wetlands. The Washington State Wetland Function Assessment Project (Hruby et. al. 1997) defines depressional flow-through wetlands as follows:

> Depressional wetlands occur in topographic depressions, that exhibit closed contour interval(s) on three sides and elevations that are lower than the surrounding landscape. The shape of depressional wetlands vary, but in all cases the movement of surface water and shallow subsurface water from at least three cardinal directions in the surrounding landscape is toward the point of lowest elevation in the depression. The movement of surface water in depressional wetlands is also vertical (up and down). Depressional wetlands may be isolated with no surface water inflow or outflow through a defined channel, or they may have permanent or intermittent, surface water inflow or outflow in a defined channels, that connects them to other surface waters or wetlands. Stream draining into a wetland may modify the topographic contours of the depression where they enter or exit the wetland. Depressional wetlands with channels or streams differ from riverine wetlands in that their ecosystem is not significantly modified by riverine flooding events. Headwater wetlands would be classified as depressional because overbank flooding is not a major ecological "driver."
>
> Depressional wetlands may lose water through intermittent or perennial drainage from an outlet, by evapotranspiration, and flow into the groundwater at times when they are not receiving discharge from groundwater. The Flow-through and Closed subclasses have very similar positions in the landscape that do not warrant separate geomorphic profiles. Differences between the subclasses are based on the functions they perform. The geomorphic characteristics of depressional wetlands in lowland western Washington are as follows:
>
> 1. Depressional wetlands in lowland western Washington are found in the following geomorphic settings: 1) Former kettleholes left by receding glaciers; 2) in depressions on top of clay lenses in glacial outwash, such as the area between Olympia and the Chehalis River, and 3) headwater of lowland streams, 4) alluvial terraces above the existing floodplains, and 5) depressions in glacial till.
>
> 2. Many depressional wetlands have well developed peat deposits because the outflow, if it exists, is above the base of the depression. Thus, organic matter will tend to collect.

Figure 2. Depressional Flow-Through Wetlands

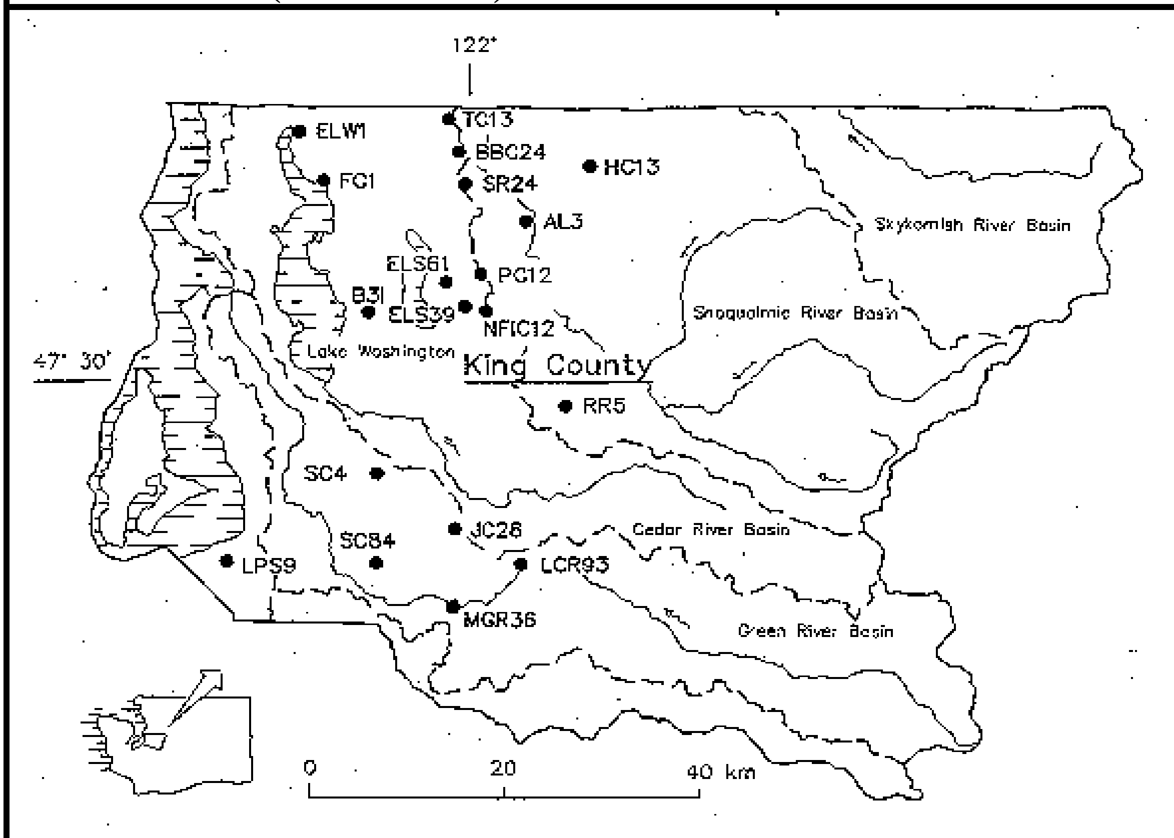


3.3. Reference Wetlands

The use of reference wetlands is central to the science of wetland function assessment, mitigation project design, and mitigation project evaluation. Reference wetlands are used to develop reference standards for the planning and design of wetland mitigation projects. Reference wetlands are defined as "a group of wetlands that represent the range of variability exhibited in a regional wetland subclass as a result of natural processes and anthropogenic disturbance (Smith 1995)." Reference wetlands are expected to demonstrate changes in structure and function in response to both natural environmental conditions and human influences (e.g.: changing land use and land cover). The range of reference wetlands may include sites that are relatively pristine as well as highly degraded. For these reasons reference wetlands are not "controls" because it is impossible to obtain the degree of similarity in natural systems implied by the scientific term control (Richter et. al. 1997). Moreover, the results that derived from these analysis are correlations, not scientific "proofs."

The Puget Sound Wetlands Stormwater Management Research Program (PSWSMRP) was organized in 1986 for the purpose of resolving questions concerning wetlands and stormwater runoff. A research program design was developed with four major components, including: a) wetland survey; b) water quality improvement study; c) stormwater impact study; and d) laboratory and special field studies. Using this research design, in 1986 the PSWSMRP initiated a long-term investigation of 19 freshwater wetlands (Figure 3) representative of wetlands in the Puget Sound lowlands. In 1996 the program was terminated and final program results, findings, and recommendations were published (Azous et. al. 1997).

Figure 3. Puget Sound Wetlands and Stormwater Management Research Program study locations (Azous et al. 1997).



3.4. Reference Standard Sites

Four of the 16 PSWSMRP study site wetlands were selected as reference standard sites. Among all reference wetlands, these are judged by an interdisciplinary team to have the highest levels of functioning (Brinson 1995). These sites included BBC24, SR 24, AL3, TC13. Reference standard wetlands are defined as: the site within a reference wetland data set from which reference standards are developed. Note that all the reference standards in this document were developed using the entire data for the 19 reference wetlands. Whenever standards were based on a smaller set of wetlands, it is noted in the discussion.

3.5. Developing Values for Variables and Indicators

Variables were selected from regional wetland function models developed by the Washington State Wetland Function Assessment Program (WSWFAP) (Hruby et al.1997) for the Puget Lowlands of western Washington. Seventeen function models were broken down to isolate 107 discrete variables. All variables were screened to determine if they served as planning and/or design criteria for establishing wetland functions. Initially, the variables were organized into lists to determine if and where indicators were required measure the variable (e.g.: the variable: *Thin-stemmed Emergent* requires no indicator; it is directly measurable). Where

indicators were required (e.g.: an indicator for hydroperiod) they were further evaluated to determine: a) if data from the PSWSMRP could provide values for the indicator; b) if values could be obtained from additional fieldwork; c) if alternative indicators existed for which PSWSMRP or other data already existed. Finally, the various strategies for obtaining values for indicators were evaluated in terms of the level of effort required to obtain measurements (e.g.: one year of gage readings to characterize and classify the hydroperiod of a wetland). If the level of effort was determined to be unreasonable with respect to the timeline for the development of these standards (one year), then alternative indicators were used or the variable was eliminated.

Additional variables not previously identified in the WSWFAP function models have been included and developed as performance standards. These new variables directly pertain to the development of mitigation planning and design criteria (as opposed to their use in function assessment). For example, the variable *Water Source* provides for the planning of surface water conveyance for the purpose of establishing wetland hydrology functions. In many cases these new variables represent wetland attributes or characteristics that are the product of the long-term research performed by the PSWSMRP (e.g.: hydroperiod classes). In other cases they represent variables recognized by the project team as being critical to the establishment of wetland functions (e.g.: designing surface water conveyance to a mitigation wetlands).

3.6. Reference Standards

Reference standards are defined (Brinson 1995) as "conditions exhibited by a group of reference wetlands that correspond to the highest level of functioning (highest sustainable capacity) across the suite of functions of the subclass." The reference standards in this report provide a range of values that represent the minimum and maximum variation in conditions found among the wetlands analyzed. These wetlands were not all examples of the highest level of function for the standard being evaluated. Overall, the conditions found represented wetlands with suburban to rural land uses in the watershed. These reference standards might more properly be described as the "reference standard range" because they represent the variability of wetlands found within a region that is rapidly urbanizing.

Initially, the reference standards were based on the reference standard sites among the 19 in the PSWSMRP study. These analysis provided reference standards representative of wetlands considered to have the highest functions for habitat. Such standards were not, however, considered to be reasonable or attainable standards for mitigation projects. Following this first effort standards were, in most cases, reformulated using all the wetlands measured for a particular variable, in order to attain the range of variation for ecological characteristics.

Reference standards values will exhibit variability based on the reference domain wetlands. The structure and function of wetlands within the reference domain will be variable with respect to changes in land use and hydrology. In addition, no one wetland site is likely to exhibit the highest level of performance for all functions when not all functions are mutually compatible (i.e.: live storage and amphibian habitat). Reference standards will generally provide a range of values that represent the normal variation of reference wetlands. For example, the reference

standard for the variable: Water Level Fluctuation is 3 to 46 cm over 19 wetlands, while the project performance standard limits mean water level fluctuation (WLF) to 21 cm annually. The difference is based on analysis showing reduced plant and amphibian diversity in wetlands with WLF greater than 21 cm.

Reference standards used to develop wetland functional assessments may differ in some respects from reference standards developed for establishing wetland functions in mitigation projects. Reference standards for wetland mitigation projects are used as planning, design and construction criteria. Our reference standards were obtained by analyzing data from a reference wetland population to determine the statistical variability or range of values associated with different ecological variables. These values for ecological variables (i.e.: the number of snags found in wetland buffers) are the reference standards. Our reference standards differ from the rapid measurements typically used to develop reference standards (e.g.: for developing function assessments) because these standards do not reveal developmental trends or performance benchmarks. Hydroperiod characterization, for example, may require long-term analysis of the timing, frequency, and duration of saturation or inundation through both “wet,” “dry,” and “normal” water years. For these reasons long-terms studies of reference wetlands provide robust measures of wetland variables.

3.7. Project Performance Standards

Project performance standards are the measures of success used to evaluate the development of ecological characteristics associated with mitigation projects at some point in time. Project performance standards are based on reference standards and may require scaling and adjustment to account for the site conditions and time lags in the establishment of specific wetland characteristics. Project performance standards are used in conjunction with mitigation project goals and objectives. Whereas goals are broad statement that generally define the intent or purpose of a project, and objectives specify the measurable actions for achieving the goals, project performance standards are the benchmarks used to determine when an objective has been met.

The project performance standards generally describe the average or better values for the development of different characteristics within 5 years following the completion of all construction activities. Many of the project performance standards are based on best professional judgment. Some examples of variables which will change over time are plant survivorship, plant cover, plant strata establishment, and woody debris establishment. Optimally, such values will be obtained from future field monitoring results of created or restored wetlands and used to adjust these project performance standards to make them more robust and truly representative of the “real-world” rate at which wetland characteristics are established.

The project performance standards have been developed for use by both mitigation project designers and regulators to evaluate trends in the development of specific function. They are particularly useful as early warning signals for identifying project problems and implementing corrective contingency actions. Trend analysis of well log data, for example, may indicate that

soil moisture regimes are not meeting project performance standards for duration of saturation or inundation.   Failure to satisfy these performance standards would trigger corrective actions, for example: re-configuring stormwater conveyance systems, site re-grading, or modifications to outlet controls.

Ultimately, reference wetlands provide the best source for the development of project performance standards. By collecting data on the ecological characteristics associated with reference wetlands, and created or restored wetlands, standards of comparison can be established by which to judge the development of wetland characteristics in compensatory mitigation projects. The use of regional reference wetland characteristics provide greater assurance that project performance standards will be reasonable (i.e.: attainable) and useful gauges of the development of wetland functions.

3.8. Application to Compensatory Mitigation Projects

These standards have been developed primarily for use in developing regional wetland mitigation banks. They provide the optimum requirements for buffer size and legal protection, hydrologic modeling, and minimum wetland size, among others. These standards may also be applied to other types of compensatory wetland mitigation projects *with appropriate scaling of the standards.*

The reference standard for the variable *Size*, for example, recommends a minimum wetland size of 5 acres. This represents a minimum size required for establishing wetlands capable of supporting the broadest assemblage of structural characteristics associated with many different functions. In the absence of established methods for performing such scaling, common sense and best professional judgment can be used to tailor project performance standards for evaluating different sizes of wetland creation and restoration projects.

For small or “routine” compensatory mitigation projects (i.e.: for road crossings of wetlands resulting in relatively small areas of impact), these standards should be directly linked to the goals and objectives of the mitigation project and used to guide planning and design. The preparation of both conceptual and final (construction) compensatory mitigation plans should follow the ‘Guidelines for Developing Freshwater Wetlands Mitigation Plans and Proposals” (Hruby et al. 1994) or other best-available technical information (e.g., provided in Restoration Ecology, Ecological Engineering, Conservation Biology). To the extent possible, use of these performance standards should be documented and the results monitored. This would allow for

The references standards for Puget lowland, depressional flow-through wetlands include functions and variables that are broadly grouped into physical, vegetative, and biological functions. Many of the ecological models used to describe wetland functions will share similar variables (related tables, spreadsheets and auxiliary analyses for each of these variables may be found in Chapter 5). In these cases the same criteria or specifications will be duplicated. In some cases new variables have been identified. These variables were not derived from the Washington State Wetland Function Assessment Program (WSWFAP) models of wetland function because they represent ecological processes or characteristics which cannot be rapidly assessed. In some instances the project performance standards serve as both performance benchmarks and as specifications because the standard is both detailed and precise.

The standards are organized according to six models addressing ecological function. They are Site Selection, Hydrology (for habitat support), General Habitat, Plant Communities, and Amphibian, Bird and Mammal Habitat Models. The Hydrology model covers standards designed to create conditions that will insure success in wetland mitigation for habitat functions. The General Habitat model covers standards considered important to providing habitat for a broad spectrum of species. The individual models for Plant Community, Amphibian, Mammal and Bird habitat are intended to be used when mitigation goals require more specific guidance. The standards for habitat replacement are based on studies of the hydrology, flora and fauna communities found in wetlands over a ten year period. These standards for creating general, plant, amphibian, bird and mammal habitat were selected because they have been found to be important criteria for measuring the contribution of a wetland to biological diversity and are supported scientifically by the reference database. Suggested monitoring protocols for demonstrating achievement of these standards are available in Monitoring Manual to Establish Reference Conditions for Freshwater Wetlands in Western Washington (Richter et. al. 1997).

Need for the Standards
These standards have been established for the purpose of locating wetland mitigation sites. Site selection refers both to landscape features that influence the movement of wildlife and nutrients, and to site characteristics that may limit the development of wetland characteristics.

Definitions and Assumptions
Site selection is defined as the location and siting of mitigation projects. These standards do not include variables requiring that the wetland catchment contain certain types of land use or land cover that would protect wetland hydrology. These were omitted because the assumption has been made that urbanization will always significantly alter wetland hydroperiods. Rare exceptions may exist where the upgradient watersheds or catchment basins to wetlands have been legally protected. In most instances, however, urbanization will increase the magnitude, frequency, and duration of wetland water levels. As a result the hydrology reference standards have been developed that include requirements for the analysis, engineering and management of the wetland hydroperiods.

The WSWFAP function models do not include site selection functions. Rather, they include "opportunity" variables that represent landscape and watershed characteristics that influence wetland functions. These can be separated into water quality and water quantity functions and variables. Water quality data from the PSWSMRP, were not, however, developed into reference standards. The WSWFAP water quantity functions and variables are based, in part on results from the PSWSMRP, indicating that hydrologic change was the most significant impact to wetland functions in urbanizing watersheds. These revealed that when the urbanization of wetland catchments reached 8-10 percent impervious area, significant increases in water level fluctuation resulted.

Scope

The site selection standards are limited to three variables. The *Corridor* and *Buffer - Upland* variables establish a landscape context for the siting of a wetland mitigation project. The *Size* variable is almost a "red-flag" variable because it requires that mitigation projects be of a specific minimum size so as to maximize the establishment of a diversity of wetland habitats.

Table 1. Reference Standards for Site Selection			
HGM Variable	Page	Reference Standard	Site Selection Standard
Corridor	52	0 - 5 Corridor Rating	Rural Wetland Standard: Corridor rating should equal or exceed a score of three Urban Wetland Standard: Corridor rating should equal or exceed a score of one. Ratings are according to the WA DOE Wetland Rating System for corridor condition.
Buffer - Upland	*45*	Favorable habitat within 500 meters ranged from 7 to 92% of the area; and within 100 meters favorable habitat ranged from 1 to 99% of the area. (19 wetlands)	Rural Wetland Standard: At least 65 percent of land within a 500 M buffer around the wetland should be comprised of forest, native vegetation, shorelines or water, which are protected by native growth or conservation easements or other legal structures. Urban Wetland Standard: At least 80 percent of land within a 100 M buffer around the wetland should be comprised of forest, native vegetation, shorelines or water, which are protected by native growth or conservation easements or other legal structures.
Size	*85*	0.6 ha - 11 ha (1.5 to 27 acres).	Rural Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres). Suburban Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres) or, if smaller, should be connected to another natural habitat area.

Need for the Standards

The frequency, depth, and duration of inundation both create and control the functions associated with wetlands. Water has long been recognized as the “forcing function” behind the development of wetland characteristics. Despite the importance of hydrology it is often the most poorly managed element in the siting and design of compensatory wetland mitigation projects. Conclusions from the PSWSMRP (Reinelt et al. 1991) revealed that wetland hydroperiods are altered with watershed development due to urbanization. As impervious land cover grows with urbanization, the magnitude, frequency, and duration of wetland water levels also increases. This results in higher wetland water levels more frequently that last for longer duration’s of time. These hydroperiod changes have a negative impact on plant and animal communities adapted to pre-urbanization watershed characteristics.

Relationship to Function Models

Many of the variables identified as reference and project performance standards are different from those variables found in the WSWFAP function models. Wetland infiltration, for example, does not occur as a defining characteristic of depressional flow-through wetlands. In fact, most depressional flow-through wetlands exist because of a perched water table. Designing and creating a depressional flow-through wetland, therefore, requires the establishment of a substrate that will prevent infiltration and provide for a perched water table.

Definitions and Assumptions

Hydroperiod is defined as the seasonal occurrence of flooding and/or soil saturation; encompasses the depth, frequency, duration, and seasonal pattern of inundation. The hydrology reference standards and project performance standards provide measurable criteria for designing and verifying the attainment of specific hydrologic variables. Particular emphasis has been placed on the establishment of specific wetland hydroperiods to mitigate for the negative effects of urbanization.

Scope

These reference and project performance standards are the key characteristics that drive the development of wetland functions.

Limitations

These standards are not a “cookie-cutter” solution to the design and management of wetland hydrology. Detailed landscape analysis including field gaging, and computer modeling of the project site catchment is required to properly engineer surface water conveyance systems. Site infiltration must be properly verified using appropriate tests (e.g.:, pump tests). Failure to fully analyze and verify that these variables have been provided for will almost guarantee project failure.

Table 2. Reference Standards for Hydrology Functions

Variable	Page	Reference Standard	Project Performance Standard
Water Source	90	The quantity, timing, and duration of water are sufficient to sustain wetland characteristics	Surface water contributions are designed and routed to the wetland.
Infiltration	70	A perched water table exists.	Glacial till, lacustrine silts or clays, or bedrock with an infiltration rate or saturated permeability of less than 1 x 10-6 m/s or 0.14 inches per hour will underlie the wetland.
Hydroperiod	67	Stable base with low events to Fluctuating base with high events.	On average wetland hydroperiod should have a fluctuating or stable base flow with low event fluctuations.
Depth	54	3 - 4 WET depth classes	The varying depths of water in the wetland during most dry seasons should equal or exceed three WET depth classes.
Fluctuation	62	3 - 46 cm (0.09 to 1.54 ft.)	Limit mean water level fluctuation (WLF) to 21 cm (8.4 inches) annually.
Outlet	79	Outlets varied from open channel to highly constricted and outlet structures with culverts, streams, beaver dams, roads, bulkheads and catch basins.	The outlet control should approximate a low beaver dam; either acting as a broad crested weir or as a leaky berm.
Flow	61	< or > 5cm/sec (0.15ft./sec.)	Flow velocity of wetland waters should be minimized to the extent possible.

Need for the Standards
A common assumption and bias in the development of these planning and design standards is that structural complexity increases habitat in wetlands. Structure is used as a surrogate for fauna habitat because a considerable body of literature exists with respect to the breeding, feeding, and refuge needs of different faunal species. In order to establish habitat structure it is not, however, sufficient to plant hydrophytic plants in low (e.g.: wet) spots. Establishing highly functioning wetlands requires a holistic design strategy involving thorough site analysis, hydrologic engineering, detailed elevation and grading plans, and routine monitoring and management involving both maintenance and contingency plans.

Relationship to Function Models
The variables identified as reference and project performance standards share the same variables as those found in the WSWFAP function models.

Definitions and Assumptions
General habitat is defined as the structural characteristics or processes present in a wetland and its surrounding landscape that indicate a general suitability as habitat for a broad range of species. It also includes processes or structural characteristics within a wetland that help maintain ecosystem resilience (Hruby et. al. 1997).

Scope
These standards combine many of the key variables that determine the development of wetland functions.

Table 3. Reference Standards for General Habitat Functions			
Variable	Page	Reference Standard	Project Performance Standard
Buffer - Wetlands	***42***	0 - 5 Buffer Rating	Rural Wetland Standard: Buffer condition should equal or exceed a score of 3 according to the WA DOE Wetland Rating System. Urban Wetland Standard: Buffer condition should equal or exceed a score of two according to the WA DOE Wetland Rating System.
Canopy Closure	***48***		

Table 3. Reference Standards for General Habitat Functions

Variable	Page	Reference Standard	Project Performance Standard
Hydroperiod	***67***	Stable base hydrograph with low storm event fluctuations to fluctuating base hydrograph with high event fluctuations.	The wetland hydroperiod should have a stable (permanent) or low fluctuating (seasonal) base hydrograph with infrequent storm event fluctuations.
Depth	***54***	3- 4 WET water depths.	The varying depths of water in a wetland between February 1st and June 15th should equal or exceed three.
Land-Water Interspersion	***73***	4 -10 Rating	Rural and Urban Wetland Standard: Wetland should have an interspersion rating of 8 or greater meaning that the land to water boundaries should be sinuous with 25% to 75% open water or curvilinear and with between 6% and 95% open water.

Need for the Standards

Wetland plant communities provide unique habitats for many species and play a critical role in maintaining the ecological integrity of a watershed. Significantly, a major finding of the PSWSMRP was that many small wetlands had high plant species diversity relative to larger wetlands and were important contributors to regional biodiversity. Moreover, plant richness and structural diversity in natural wetlands was found to be much higher than is indicated by current planting design standards for wetland mitigation.

Relationship to Function Models

The variables identified as reference and project performance standards share the same variables as those found in the Washington State Wetland Function Assessment Program function models. The variable: *Distribution* is an exception and represents the distribution of different plant associations (Cowardin class) within a wetland. These values are products of the long-term studies performed by the PSWSMRP; such values would not be obtained through the rapid field assessment methods used by the WSWFAP. One variable *Vmature*, represents the density of mature trees in the wetland. This variable was not measured by the PSWSMRP.

Definitions and Assumptions

Habitat for Plant Communities is defined as the wetland processes and characteristics that help maintain a high number of plant communities within a wetland (Hruby et. al.1997).

Basis for the Standards

The following standards for plant habitat replacement are based on studies of the plant communities found in 26 wetlands over a ten year period (Azous 1991, Cooke 1993). These standards for creating plant habitat were selected because they have been found to be important criteria for measuring the contribution of a wetland to biological diversity and are supported scientifically by the reference database.

Table 4. Reference Standards for Plant Community Functions			
Variable	Page	Reference Range	Performance Standard
Habitat Classes	64	2-4 Cowardin classes	The number of distinct Cowardin habitat classes present in the wetland should equal or exceed three.
Dominants	*58*	PEM: 14-75% PSS: 20-48% PFO: 22-67% PAB: 17-80% BOG: 63-69%	Limit the number of dominant plant species present (dominant defined as >10% cover over the entire wetland) to 50% of the total number of species within each Cowardin class with the exception of the aquatic bed class (PAB) which may range up to 80% of the total species and bogs which may range up to 70%.
Richness	83	17 - 94 species	Total species richness in a created wetland should equal or exceed 60 species.
Distribution-PEM	56	24 - 100%	In the emergent zones a minimum of 55% of the plant species should be obligate or FACW.
Distribution - PSS	56	18 - 68%	In the scrub shrub zone a minimum of 40% of species should be obligate or FACW.
Distribution - PFO	56	15 - 47%	In the forested zones, a minimum of 30% of species should be obligate or FACW.
Non-Native	75	0 - 7 species 0 - 67% of the vegetation sampling stations.	The percent of area covered by weed species should not exceed 15% of the wetland or 0.5 acre of contiguous coverage, whichever is greater, and, if exceeded, appropriate control procedures should be implemented.
Strata	87	>3 Strata	At least three strata must be present in the plant community structure within the wetland, with the exception of sedge meadows or other wetland types identified as exceptions to this standard.

Need for the Standards

Amphibians include frogs, toads, salamanders and newts. They occupy many different wetland habitats, using specific water depth and plant stem preferences during a short, late winter-early spring breeding season. As adults, many amphibians require wetland buffer or upland habitats. Because of their dependence on wetlands for breeding, many amphibians are particularly sensitive to changes in land use that diminish water quality, increase the magnitude, frequency and duration of water levels, and reduce or eliminate migratory corridors. The standards include specific guidelines for planning and designing mitigation projects to provide preference for the establishment of amphibian breeding, feeding, and refuge habitats. They reveal that interspersion should be more extensive than is currently found in mitigation project designs, and that solar orientation contributes to amphibian breeding success.

Relationship to Function models

Values have been developed for all of the variables used in the WSWFAP models. The variable *Orientation* has been added to provide solar orientation siting and design guidance.

Definitions and Assumptions

Amphibian Habitat is defined as the wetland processes and characteristics that contribute to the feeding, breeding, or refuge needs of amphibian species using wetlands of the regional subclass (Hruby et. al. 1997).

Table 5. Reference Standards for Amphibian Habitat Functions

Variable	Page	Reference Standard	Project Performance Standard
Buffer - Wetland	*42*	0 - 5 Buffer Rating	Rural Wetland Standard: Buffer condition should equal or exceed a score of three according to the WA DOE Wetland Rating System. Urban Wetland Standard: Buffer condition should equal or exceed a score of two according to the WA DOE Wetland Rating System.
Corridor	*50*	0 - 5 Corridor Rating	Rural Wetland Standard: Corridor rating should equal or exceed a score of three Urban Wetland Standard: Corridor rating should equal or exceed a score of one. Ratings are according to the WA DOE Wetland Rating System.
Edge Structure	*60*	Transects measuring the shoreline slope ranged from 1 - 10 %.	The water land edge should be gradually sloping (not exceeding 10%) with a high length of shoreline to area ratio (>1.5).
Hydroperiod	*67*	Stable base with low events to Fluctuating base with high events.	On average wetland hydroperiod should have a fluctuating or stable base flow with low event fluctuations.
Flow	*61*	< 5cm/sec (0.15 ft./sec.)	See Variable description.
Land-Water Interspersion	*73*	4 - 10 Interspersion Rating	Rural and Urban Wetland Standard: Wetland should have an interspersion rating of 8 or greater meaning that the land to water boundaries should be sinuous with 25%to 75% open water or curvilinear and with between 6% and 95% open water.

Table 5. Reference Standards for Amphibian Habitat Functions			
Variable	Page	Reference Standard	Project Performance Standard
Woody Debris	*94*	40 to 214 m^3 small: 11 to 40% medium: 26 to 31% Large: 30 to 60% 7:1 to 17:1 coniferous to deciduous wood 49 to 193 snags per hectare	Average volume of woody debris should equal or exceed 135 m^3 per hectare. Of this woody debris, a minimum of 30% of the volume (63 m^3) should have a Decay/Size rating of Large, that is, composed of logs at least 21 cm in diameter and greater than 6 meters in length from within any decay class. The ratio of coniferous to deciduous woody debris should be 7:1. The average number of snags should equal or exceed 115 per hectare.
Buffer-Upland	*45*	Favorable habitat within 500 meters ranged from 7 to 92% of the area; and within 100 meters favorable habitat ranged from 1 to 99% of the area.	Rural Wetland Standard: At least 65 percent of land within a 500 M buffer around the wetland should be comprised of forest, native vegetation, shorelines or water, which are protected by native growth or conservation easements or other legal structures. Urban Wetland Standard: At least 80 percent of land within a 100 M buffer around the wetland should be comprised of forest, native vegetation, shorelines or water, which are protected by native growth or conservation easements or other legal structures.
Fluctuation	*62*	Varied from 3 to 46 cm (0.09 to 1.54 ft.).	Limit mean water level fluctuation (WLF) to 21 cm annually.
Thin-Stemmed Emergents	*88*	Varied from less than 10%of the wetland to 30 to 50% of the wetland area.	Wetlands created for amphibian habitat should have thin-stemmed emergent plants comprise at least 30% or more of the total wetland area.

Table 5. Reference Standards for Amphibian Habitat Functions			
Variable	Page	Reference Standard	Project Performance Standard
Interspersion	*71*	0 - 7 Interspersion Classes	Wetland should have at least a moderate vegetation interspersion rating equal to or greater than six. A moderate interspersion rating is one that has at least two wetland classes and an upland class with a complex pattern of interspersion.
Size	*85*	0.6 ha - 11 ha (1.5 to 27 acres).)	Rural Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres). Urban Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres) or, if smaller, should be connected to another natural habitat area.
Orientation	*78*	98% of amphibian eggs were on the north shore, with 68% of these along the northwestern shore.	Maximize solar exposure and opportunity for amphibian breeding by establishing gradual (i.e.: 10:1) slopes in the northwestern quadrants of wetlands.

Need for the Standards

Mammal habitat includes structural characteristics that provide breeding, feeding, and refuge habitat predominantly for terrestrial mammals that require wetland characteristics for some or a portion of their life history. These are important because large mammals (e.g., beaver, muskrat) may be “keystone” species that direct large physical attributes of wetlands, whereas smaller mammals play subtle, but significant role in wetland functions such as nutrient cycling. Small mammals are significant herbivores and insectivores, and because of their high fecundity are often important food for carnivores, raptors.

Relationship to Function models

Values have been developed for all of the variables used in the WSWFAP models.

Definitions and Assumptions

The Mammals standard is defined as habitat for aquatic fur-bearers [that include] wetland features and processes which support one or more life requirements of economically important aquatic or semi-aquatic mammals. Although the WSWFAP defines this standard in terms of mammals that are wetland-dependent, the reference standard does not emphasize the development of habitat for these species. Generally, compensatory wetland mitigation is the required when land use development occurs, usually in urbanizing landscapes. In these urban landscapes the establishment of habitat for aquatic-fur bearing mammals may be inadvisable due to inevitable conflicts arising between the behavior of these species and neighboring humans. As a result, these standards more favorable to wetland small mammals and some terrestrial species that heavily utilize wetland buffers (e.g.: deer and field mice, voles, shrews).

Table 6. Reference Standards for Mammal Habitat Functions			
Variable	Page	Reference Standard	Project Performance Standard
Buffer - Wetland	*42*	0 -5 Buffer Rating	Rural Wetland Standard: Buffer condition should equal or exceed a score of three according to the WA DOE Wetland Rating System. Urban Wetland Standard: Buffer condition should equal or exceed a score of two according to the WA DOE Wetland Rating System.
Depth	*54*	3- 4 WET water depths.	The varying depths of water in a wetland between February 1st and June 15th should equal or exceed three.
Corridor	*52*	0 - 5 Corridor Rating	Rural Wetland Standard: Corridor rating should equal or exceed a score of three. Urban Wetland Standard: Corridor rating should equal or exceed a score of one. Ratings are according to the WA DOE Wetland Rating System.
Herbs	*66*	Less than 10% to 50-80%.	Wetlands designed to support mammal habitat should have 30% to 50% of the total area planted with herbs.
Edge Structure	*60*	The shoreline slope ranged from 1 - 10%.	The water land edge should be gradually sloping (not exceeding 10%) with a high length of shoreline to area ratio (>1.5).
Land -Water Interspersion	*73*	4 - 10 Interspersion Rating	Rural and Urban Wetland Standard: Wetland should have an interspersion rating of 8 or greater meaning that the land to water boundaries should be sinuous with 25%to 75% open water or curvilinear and with between 6% and 95% open water.

Need for the Standards
Bird habitat includes vegetation communities and structural characteristics that provide breeding, feeding, and refuge habitat for many species and life history stages. Wetland characteristics such as size, open water vegetation interspersion, snag density etc., all have been shown to correlate with bird richness. Consequently, standards that describe the best characteristics and distribution of these features will optimize bird usage of a site.

Relationship to Function models
Values have been developed for all of the variables used in the WSWFAP models with the addition of *Size*. This variable represents the results of long-term data correlating bird species richness to a range of different sized wetlands.

Definitions and Assumptions
Bird Habitat is defined as the process and environmental conditions in a wetland that provide habitats or life resources for species of wetland-dependent birds (Hruby et. al. 1997).

Table 7. Reference Standard for Bird Habitat Functions

Variable	Page	Reference Standard	Project Performance Standard
Buffer - Wetland	*42*	0 - 5 Buffer Rating	Rural Wetland Standard: Buffer condition should equal or exceed a score of three according to the WA DOE Wetland Rating System. Urban Wetland Standard: Buffer condition should equal or exceed a score of two according to the WA DOE Wetland Rating System.
Cavities	*50*	Cavity Trees: 4 to 24 per hectare. The number of cavities per hectare ranged from 58 to 282 and averaged 154 for all wetlands.	There should be a minimum of 14 cavity trees per hectare with an average of 11 cavities per tree for a minimum total of 154 cavities per hectare.
Strata	*87*	All wetlands surveyed had at least three strata within their community structure.	At least three strata must be present in the plant community structure within the wetland, with the exception of sedge meadows or other wetland environments identified as exceptions to this standard.
Interspersion	*71*	3 -7 Interspersion Rating	Wetland should have at least a moderate vegetation interspersion rating equal to or greater than six. A moderate interspersion rating is one that has at least two wetland classes and an upland class with a complex pattern of interspersion.
Woody Debris	*94*	40 to 214 m3. small: 11 to 40% medium: 26 to 31% Large: 30 to 60% 7:1 to 17:1 coniferous to deciduous wood 49 to 193 snags per hectare	Average volume of woody debris should equal or exceed 135 m3 per hectare. Of this woody debris, a minimum of 30% of the volume (63 m^3) should have a Decay/Size rating of Large, that is, composed of logs at least 21 cm in diameter and greater than 6 meters in length from within any decay class. The ratio of coniferous to deciduous woody debris should be a minimum of 7:1. The average number of snags should equal or exceed 115 per hectare.
Open Water	*77*	Nine out of nineteen wetlands had at least 10,000 m^2 (0.25 acres) of open water.	There should be a minimum of 10,000 m^2 (0.25 acres) of open water available within the wetland.

Table 7. Reference Standard for Bird Habitat Functions

Variable	Page	Reference Standard	Project Performance Standard
Habitat Classes	*64*	2 - 4 Cowardin Class	The number of distinct Cowardin habitat classes present in the wetland should equal or exceed three.
Edge Structure	*60*	The shoreline slope ranged from one to 10 %.	The water land edge should be gradually sloping (not exceeding 10%) with a high length of shoreline to area ratio (>1.5).
Proximity - Freshwater	*81*	1.04 to 3.9 km (0.51 to 2.42 mi)	Wetland should be located within 1.6 km (1 mile) of a freshwater lake of 20 acres or greater.
Canopy Closure	*48*	13 - 100% of wetland area.	The percent of canopy closure should range between 15 % and 60% of the wetland area.
Size	*85*	0.6 ha - 11 ha (1.5 to 27 acres)	Rural Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres). Urban Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres) or, if smaller, should be connected to another natural habitat area.

This chapter provides information on the purpose, requirements and analytical methods associated with each variable in the function models. This sections also identifies the relationships between the HGM function assessment models developed by the Washington State Function Assessment Program, (Hruby et al. 1997) and functions and variables used to establish the Reference Standards and Project Performance Standards in this report.

Definitions
These are provided for each function and variable, using definitions established by, or consistent with, those generated by the Washington State Function Assessment Program. When new variables were identified and developed as Reference Standards and Project Performance Standards, definitions were developed by the project team.

Reference Standards
These are the conditions exhibited by a group of reference wetlands that correspond to the highest level of functional capacity (highest, sustainable level of functioning) across the suite of functions performed by the regional wetland subclass (Smith 1995). These reference standards are presented as ranges because the reference wetlands from which data was obtained represent a range of variability as a result of natural processes and anthropogenic disturbance

Project Performance Standards
These represent the measurable benchmarks used to evaluate the development of ecological characteristics associated with mitigation projects at some point in time, generally five years following the completion of all construction. They are used as a standard of comparison against which the mitigation project can be compared. They are provided, along with more detailed guidance on verifying when Project Performance Standards have been satisfied.

Related HGM Variables and **Related HGM Functions**
Refer to function models and variables being developed by the Washington State Function Assessment Program.

Rational
This describes the reasoning guiding development of the standards.

Methods
These refer to the field survey, data collection and statistical protocols used.

Tables
The tables represent data obtain from other studies and are generally cited except for field research and analysis performed by Azous 1997 [this report]. Shaded areas within the tables indicate the reference standard sites used to evaluate and develop particular reference standards.

Definition: Land use patterns within specified distance of the edge of the wetland. Wetland buffer plant structure and level of disturbance (based on Washington State DOE Wetland Rating System (WSDOE 1993)).

Reference Standard: 0 - 5 according to the WADOE Wetland Rating System (Table 8).

Project Performance Standard: Two standards are provided: 1) a Rural Wetland Standard: Buffer condition should equal or exceed a score of three using the WA DOE Wetland Rating System; and 2) an Urban Wetland Standard: Buffer condition should equal or exceed a score of two using the WA DOE Wetland Rating System.

Rural Wetland Standard:
The site design should demonstrate a protected (e.g., native growth or conservation easement) forest, scrub, native grassland, or open water buffers wider than 100' for more than 1/2 of the wetland circumference, or forest, scrub, grasslands, or open water buffers for more than 50' around 95% of the circumference (Table 8).

Urban Wetland Standard:
The wetland design should demonstrate a protected (e.g., native growth or conservation easement) forest, scrub, native grassland, or open water buffers wider than 100' for more than 1/4 of the wetland circumference, or forest, scrub, grasslands, or open water buffers wider than 50' for more than 50% of the wetland circumference; or free of roads, buildings or paved areas within 100' of the wetland for more than 95% of the wetland circumference (Table 8).

Table 8. Wetland buffer rating system (Washington State Department of Ecology, 1993)

Rating	Description
5 =	Forest, scrub, native grassland or open water buffers are present for more than 100' around 95% of the circumference.
3 =	Forest, scrub, native grassland, or open water buffers wider than 100' for more than 1/2 of the wetland circumference, or forest, scrub, grasslands, or open water buffers for more than 50' around 95% of the circumference.
2 =	Forest, scrub, native grassland, or open water buffers wider than 100' for more than 1/4 of the wetland circumference, or forest, scrub, grasslands, or open water buffers wider than 50' for more than 50% of the wetland circumference.
2 =	No roads, buildings or paved areas within 100' of the wetland for more than 95% of the wetland circumference.
1 =	No roads, buildings or paved areas within 25' of the wetland for more than 95% of the circumference, or, no roads, buildings or paved areas within 50' of the wetland for more than 50% of the circumference.
0 =	Paved areas, industrial areas or residential construction (with less than 50' between houses) are less than 25 feet from the wetland for more than 95% of the circumference of the wetland.

Related HGM Variables: *Vbuffcond*

Related HGM Functions: General Habitat, Amphibian Habitat, Bird Habitat, Mammal Habitat

Rational: Land use patterns adjacent to a wetland significantly affect the availability of cover, food and other habitat conditions that influence the diversity of mammal, amphibian and bird populations at a wetland. Buffer condition of ratings the 19 wetlands we evaluated ranged from zero to five (Table 9). The buffer condition of those wetlands selected for their high biodiversity are shown as shaded and ranged from three to five. We used land conditions correlating to these ratings as the performance standard for rural areas. A performance standard of two was selected for urban growth areas based on the physical limitations placed on habitat within urban landscapes.

Table 9. Percent favorable land within 10 and 100 m buffers and corresponding WSDOE (1993) buffer ratings. Favorable lands include protected forests, native vegetation, shorelines and water.

	Percent of Favorable Land within Respective Buffers		
Wetland ID	33 Ft. (10 M)	330 Ft. (100 M)	WA DOE Rating*
AL3	1.00	1.00	5
B3I	0.24	0.10	1
BBC24	0.91	0.87	5
ELS39	0.69	0.53	0
ELS61	0.88	0.57	2
ELW1	0.79	0.72	2
FC1	0.55	0.41	2
HC13	1.00	0.96	5
JC28	0.81	0.62	2
LCR93	0.85	0.85	4
LPS9	0.50	0.39	2
MGR36	0.87	0.93	4
NFIC12	0.60	0.57	3
PC12	0.93	0.96	5
RR5	0.90	0.90	3
SC4	0.86	0.56	2
SC84	0.93	0.83	4
SR24	0.93	0.97	5
TC13	1.00	0.92	4

* 4 = Rated between 3 and 5.

Methods: Buffers of each of the wetlands in the study were categorized using the criteria shown in Table 8. The categorization used data obtained from a GIS inventory of land uses in the watersheds of the study wetlands (Taylor 1993). In 1995, these data were

corroborated using 1995 satellite images to more specifically identify land uses within 10 m and 100 m wide bands of the surrounding landscapes. The results furnished quantitative and graphical representations of land use patterns. This data was used to analyze the effects of urbanization on wetlands and showed a correlation of specific land uses in the buffer with wildlife usage (Azous and Horner 1997). We then applied findings from these analysis to the Washington State buffer rating system.

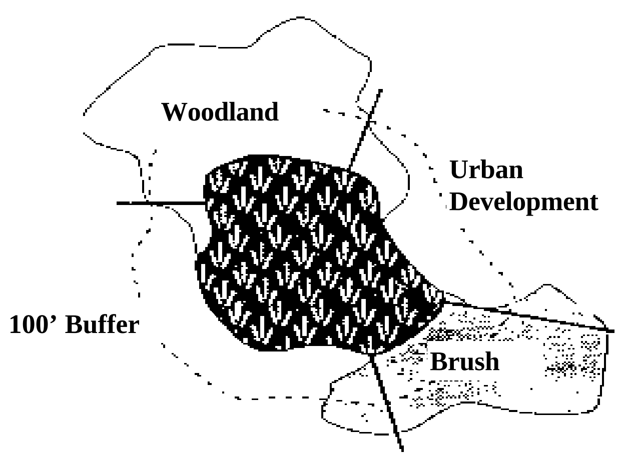
Definition: The types and aerial coverage of land uses within 1 km of the wetland.

Reference Standard: Favorable habitat within 500 m ranged from 7 to 92% of the area; and within 100 m favorable habitat ranged from 1 to 99% of the area.

Project Performance Standard: 1) Rural Wetland Standard: At least 60 percent of land within a 500 m buffer around the wetland should be comprised of favorable cover (e.g., forest, native vegetation, shorelines or water protected by native growth or conservation easements, 2) Urban Wetland Standard: At least 60 percent of land within a 100 m buffer, or 80 percent within 30 m around the wetland should be comprised of favorable cover .

Wetland site design should demonstrate that buffers adjacent to wetland meet the conditions described above using recorded easements and notice on titles of protected buffers.

Figure 4. Wetland and Upland Buffer



Rational: We found that land use adjacent to a wetland was related to the richness of native amphibian, bird and mammal populations. We found statistically significant relations between favorable land coverage and amphibian richness within concentric areas of 10, 100, 500 and 1000 meters. In general, wetlands adjacent to a high percentage of forest land were more likely to have richer populations of native amphibians. The significance of this relationship was weakest at 10 m ($R = 0.57$, $p = 0.01$) and strongest at 500 m ($R = 0.66$, $P = 0.004$) (Richter and Azous 1997 a, b, c). We found that species richness of birds known to avoid human development (avoiders) increased over the ten year study period primarily in wetlands with high percentages of adjacent forest land within 500 meters (Mann-Whitney (MN), $p < 0.09$) whereas they decreased among the already urban wetlands and in those where land use changes decreased available watershed habitat Richter and Azous 1997d). Critical to highly diverse wetland small mammal communities was the percent of forest cover within 500 to 1000 meters (R 0.55, p 0.02) (Richter and Azous 1997c).

The percentage of favorable habitat ranged from one to 99% within 100 meters and from seven to 93% at 500 meters. The high biodiversity wetlands ranged from 81 to 92% at 100 meters and from 63 to 93% at 500 meters (Table 10. The percentage of favorable habitat within 500 and 1000 m (Richter and Azous 1997a).

Table 10. The percentage of favorable habitat within 500 and 1000 m (Richter and Azous 1997a).		
	Percent Favorable Land Within Respective Distances	
Wetland ID	1000 M	500 M
AL3	0.71	0.67
B3I	0.15	0.07
BBC24	0.67	0.63
ELS39	0.42	0.35
ELS61	0.66	0.47
ELW1	0.48	0.60
FC1	0.34	0.35
HC13	0.89	0.92
JC28	0.45	0.42
LCR93	0.59	0.62
LPS9	0.28	0.28
MGR36	0.66	0.69
NFIC12	0.62	0.60
PC12	0.91	0.90
RR5	0.81	0.80
SC4	0.29	0.24
SC84	0.35	0.50
SR24	0.86	0.93
TC13	0.80	0.76

Method: GIS was used to analyze the effects of urbanization on wetlands allowing the linking of effects with specific land use changes associated with urban development. A geographical information system (GIS) was used to inventory land uses in the watersheds of the study wetlands (Taylor 1993). In 1995, further information was developed for 10m, 100m, 500m and 1000m wide bands of the surrounding landscapes using 1995 satellite images. The GIS furnished quantitative and graphical representations of land use patterns according to a standard land use classification scheme. Land uses were classified according to a standard land use classification scheme. The GIS provided the areas of watersheds, wetlands, and land uses and vegetative cover within 1000 M of the wetland.

The combinations of vegetative cover and land use within the 10, 100, 500 and 1000 M bands was statistically compared to the richness of amphibian, bird and mammal populations. The conditions of adjacent land use found among the wetlands with the best faunal communities was used to determine the standard.

Definition: Percent of canopy closure of woody vegetation over the entire wetland higher than 2 m. [Assessed for the shrub and/or forested communities present within the wetland which are identified as Cowardin class (i.e., the wetland has areas where cover of trees or shrubs is at least 30% as defined in Cowardin 1979).]

Reference Standard: 13 - 100% of wetland area.

Project Performance Standard: The percent of canopy closure should range between 15% and 60% of the total wetland area.

Demonstration of performance standards is when the canopy closure goal is demonstrated by aerial photo analysis, field survey data, or data provided by Geographic Information System (GIS).

Related HGM Variables: *Vcanopyclos*

Related HGM Functions: Bird Habitat, General Habitat

Rational: Requirements for canopy closure are intended to insure structural complexity exists to support breeding, feeding, and cover for faunal communities. Canopy closure affects the climate of a wetland, light levels reaching the wetland ground, mineral cycling, organic matter decomposition and soil stability. Collectively these changes influence floral and faunal communities. In general greater canopy closure reduces plant richness and structural complexity which are important characteristics for breeding, feeding, and shelter.

Canopy closure ranged widely among all 19 wetlands we studied, from the a low of 13% (BBC24) to 100% (AL3 and SC84) of the wetland area. The majority of wetlands surveyed had greater than 50% canopy closure. However, among the high biodiversity wetlands, canopy coverage was generally lower, as low as 13% in BBC24 up to a maximum of 62% in SR24. Our standard is based on the best functioning wetlands for all vertebrate classes. Consequently, this requirement may be altered if it is in conflict with habitat goals for a specific targeted species with requirement outside this range.

Table 11. Percent canopy closure (woody vegetation >2 m in height) and canopy closure class (Azous and Horner 1997).

Wetland ID	Canopy closure of woody vegetation (>2m tall)	Percent Woody Veg (1997 KC GIS)	Canopy Closure Class	Total Wetlands Within Given Closure Class	Summary Ranking of Wetlands
AL3	>80%	1.0	50-80%	6	1
B3I	50-80%	0.60	30-50%	3	2
BBC24	10-30%	0.13	10-30%	3	1
ELS39	10-30%	0.23	>80%	7	0
ELS61	>80%	0.82			
ELW1	>80%	>80%			
FC1	30-50%	30-50%			
HC13	50-80%	.63			
JC28	50-80%	0.6			
LCR93	10-30%	0.27			
LPS9	50-80%	50-80%			
MGR36	>80%	0.84			
NFIC12	>80%	0.79			
PC12	30-50%	30-50%			
RR5	30-50%	0.51			
SC4	>80%	0.92			
SC84	>80%	1			
SR24	50-80%	0.62			
TC13	50-80%	0.57			

Methods: Canopy coverage of woody vegetation was determined from GIS analysis and also verified through categorization of aerial photos. Canopy closure was measured as the proportion of wetland area with a closed canopy of woody vegetation greater than 2 meters.

Definition: Nesting cavities in standing trees suitable for birds and mammals.

Reference Standard: Cavity trees: 4 to 24 per hectare. The number of cavities per hectare ranged from 58 to 282 and averaged 154 for all wetlands.

Project Performance Standard: There should be an average of 14 cavity trees per hectare (representing an average of 11 cavities per tree for a total of 154 cavities per hectare).

Field survey data should demonstrate an average of 14 cavity trees per hectare with an average of 11 cavities per tree for a total of 154 cavities per hectare. Trees and cavities should preferably be clustered into several small groupings.

Related HGM Variables: *Vcavity*

Related HGM Functions: Bird Habitat, General Habitat

Rational: Performance standards for cavities were developed from data obtained in special snag and broken-top tree surveys at four wetlands exhibiting high bird and mammal richness. Our survey showed between 4 and 24 cavity trees per hectare. Table 12 shows the number of cavity trees in all four wetlands as well as the number of cavity trees per hectare. We counted an average of 14 cavity trees per hectare among four wetlands and used this number as the basis for our performance standard.

Table 12. Count of cavity trees per hectare within 16 m (50 ft) belt transects of transect lines.

Count of Cavity Trees	Wetland			
Transect Line	AL3	BBC24	SR24	TC13
Transect Line @ 0 ft.	9		8	8
Transect Line @ 25 ft.		31		
Transect Line @ 50 ft.	18		30	1
Transect Line @ 75 ft.		3		
Grand Total	27	34	38	9
Number of Cavity Trees per Hectare	13	15	24	4
Average Number of Cavity Trees per Hectare All Wetlands	14			

We counted 124 - 360 total cavities among the wetland surveyed, or 58 - 282 cavities per hectare (Table 13). We calculated an average of 154 cavities per acre among all four wetlands (Table 13). The standard of 11 for the average number of cavities per cavity tree was based on the average number of cavities found in cavity trees among all the wetlands. We found both cavity trees and cavities within trees to be clustered rather than evenly distributed and suggest a similar random placement of cavities and cavity trees in wetland designs.

Table 13. Count of number of cavities per wetland and per hectare

Count of Number of Cavities	Wetland			
Transect Line	AL3	BBC24	SR24	TC13
Transect Line @ O ft.	124	0	60	114
Transect Line @ 25 ft.	0	159	0	0
Transect Line @ 50 ft.	236	0	391	10
Transect Line @ 75 ft.	0	78	0	0
Total Cavities/Wetland	360	237	451	124
Total Sample Area M^2	21094	22554	15979	21225
Number of Cavities per Hectare:	171	105	282	58
Average number of cavities/tree	13	7	12	14
Average Number of Cavities per Hectare, All Wetlands:		154		
Average number of cavities/tree: All wetlands		11		

<u>Methods</u>: We counted trees with cavities within 16 m (8m of either side of the transect line) of a known length transect within four wetlands that exhibited the highest amphibian, bird and mammal richness. We also counted the number of cavities in each cavity-tree visible from the transect line. The total cavity trees and total cavities were tabulated for each wetland and the estimated density calculated on a one hectare bases. These numbers were then averaged among all wetlands to determine the performance standard.

Definition: Wetland is connected by vegetated corridors with minor human domestic animal intrusion, to other relatively undisturbed habitats (based on the WA DOE Wetland Rating System).

Reference Standards: 0 - 5 Rating.

Project Performance Standard: 1). Rural Wetland Standard: Corridor rating should equal or exceed a score of three. 2) Urban Wetland Standard: Corridor rating should equal or exceed a score of one.

Wetland site design should demonstrate the existence of corridors meeting the performance standards which are protected by physical structures such as fences and signs, and legal covenants, such as native growth or conservation easements.

Related HGM Variables: Vcorridor

Related HGM Functions: General Habitat Functions, Amphibian Habitat, Aquatic Fur-bearers Habitat

Table 14. Wetland buffer rating system (Washington State Department of Ecology, 1993)

Rating	Description
5 =	The wetland is connected to, or part of, a riparian corridor at least 100' wide, connecting two or more wetlands; or, there is an upland connection present >100' wide with good forest or shrub cover (>25% cover) connecting it with a Significant Habitat Area.
3 =	The wetland should be connected to another Habitat Area with either a 1)a forested/shrub corridor<100' wide, or 2) a corridor that is >100' wide, but has a low vegetative cover less than 6' in height.
3 =	The wetland is connected to, or part of a riparian corridor between 50 - 100' wide with scrub/shrub or forest cover connection to other wetlands.
1 =	The wetland should be connected a to another Habitat Area with at least a narrow corridor (<100') of low vegetation (<6' in height) established.
0 =	The wetland and its buffer (if the buffer is less than 50' wide) are completely isolated by development (urban, residential with a density greater than 2/acre, or industrial).

Rational

Table 15 indicates that the wetlands we studied had corridor ratings ranging from zero to five. Among the high biodiversity wetlands corridor ratings ranged from three to five and served as the performance standard for rural wetlands (shown in the shaded bars in Table 15). The corridor performance requirement for wetlands in the urban growth region was reduced to one in recognition of realistic land use patterns within the urban zones.

Table 15. Range of corridor ratings found among wetlands surveyed.

WETLAND ID	Percent of Favorable Land Within 33 Ft. (10 M)	Percent of Favorable Land Within 330 Ft. (100 M)	Connect stream	Connect Lake	WA Rating	Notes from Aerial Photo Interpretation
AL3	100.00%	100.00%	1	no	5	
B3I	24.87%	10.02%	no	yes	0	Isolated
BBC24	90.96%	86.72%	1	no	3	
ELS39	32.00%	20.00%	2	no	0	Isolated. Houses and Road. GIS data covered adjacent wetland.
ELS61	88.08%	56.97%	1	no	1	
ELW1	79.41%	71.60%	no data	yes	2	Connected to Lake Washington
FC1	55.14%	41.31%	no data	no	1	Connected to Lake
HC13	100.00%	96.16%	4	no	4	
JC28	81.14%	61.87%	1	no	0	Development surrounding
LCR93	85.23%	84.56%	1	no	3	
LPS9	57.40%	38.63%	no data	no	0	Development surrounding
MGR36	86.84%	93.34%	no	yes	3	
NFIC12	63.75%	56.90%	yes	no	4	
PC12	92.65%	96.49%	no data	no	5	
RR5	90.43%	89.69%	1	no	3	
SC4	85.58%	55.68%	1	no	2	not isolated but built up
SC84	93.56%	57.00%	3	no	2	not isolated but built up
SR24	92.51%	96.69%	1	no	5	
TC13	100.00%	91.50%	no	no	3	

Methods: The corridor ratings of each of the study wetlands were categorized using the criteria shown in Table 14. The categorization used data obtained from a GIS analysis of land cover within the watersheds. Information was developed for 10 M, 100 M, 500 M and 1000 M wide bands measured out from the wetland using 1995 satellite images. These data were corroborated with aerial photo analysis to more specifically identify land uses and areas that could be used as wildlife corridors.

Definition: Water depth classes present in the wetland during the dry season (based on WET water depth classes).

Reference Standard: 3 -4 WET water depths.

Project Performance Standard: The varying depths of water in a wetland between February 1st and June 15th should equal or exceed three.

Establish site grading plans for water depth classes at 0.5 ft contours. Performance will be assessed using a condensed form of the depth classes developed for WET habitat assessments (Adamus et al. 1987). These water depth classes are: less than 2.5 cm (<1 inch), 2.5-0.15 cm (1-6 inches), 15-51 cm (6-20 inches), 51-152 cm (20-60 inches), and greater than 152 cm (>60 inches).

This can be demonstrated through the preparation of an "as-built" topographic survey and cross-section showing water depth at a minimum of three different depth zones. The analysis should show the potential variation in seasonal water levels based on the monitored year in relationship to historical rainfall maximums and minimums obtained from a nearby official rainfall gauging station. If the wetland water classes are within the specified design goals, the wetland will meet the standard.

Related HGM Variables: *Vwaterdepth*

Related HGM Functions: Removing Sediments, General Habitat, Habitat for Anadromous Fish, Aquatic Fur-bearers

Rational: A range of water depths will provide habitat for different plant communities, which in turn, provide broader range of habitats for faunal communities. Shallower marsh areas offer feeding habitat for fish, amphibians, birds, small mammals. Shallow zones also provide cover for invertebrates, amphibians and seasonal rearing areas for fish. Deeper areas maintain water later through summer or the entire year thereby providing habitat for species requiring more than a single year to mature. Deep areas also provide cooler, oxygenated water of importance to aquatic species during warm conditions.

Water depth classes were measured in three wetlands. Table 16 shows that three or more of the water depth classes developed for WET habitat assessment (Adamus et al. 1987) were present in each of the wetlands.

Table 16. Water depth classes found in three surveyed wetlands					
	Water Depth Class				
Wetland	<2.5 cm (<1")	2.6 to 15 cm (1.1-6")	15.1 to 51 cm (6.1 - 20")	51.1 to 152 cm (21-60")	>152 cm (>60")
AL3	**x**	**x**	**x**		
SR24	**x**	**x**	**x**	**x**	
BBC24		**x**	**x**	**x**	

Methods: Water depths were measured by surveying the depth of water in three wetlands with average or better plant and animal richness. Transects were located from upland to upland crossing the wetland to obtain a profile of water depth in relationship to the distance from the shore. These data were then categorized according to the water depth categories shown in Table 16. A water depth class was reported when two adjacent transects shared the same class. The assumption was that the depth class likely covered the area between two transects when both shared a depth class at a similar distance from shore.

Definition: The distribution of different plant associations within a wetland (PEM, PSS, PFO).

Reference Standard:

Class (Cowardin)	Cover
PEM	24-100 %
PSS	18-68%
PFO	22-67%
PAB	15-47%

Project Performance Standard: In the PEM zone a minimum of 55% of the plant species should be obligate or FACW. In the PSS zone a minimum of 40% of species should be obligate or FACW. In the PFO zone, a minimum of 30% of species should be obligate or FACW.

Achievement of this performance standard may be demonstrated by vegetation survey data identifying the total number of species in relationship to the number of FACW and obligate species that have successfully established in the wetland for each Cowardin habitat class.

Related HGM Variables: NA

Related HGM Functions: NA

Rational: Plant richness is important to biological diversity but additionally critical is the percent of the total plant community which are wetland dependent species. The interspersion of wetland and upland species contributes to structural diversity within each Cowardin habitat class.

The ratios between FACW and obligate species to FAC, FACU and upland species was found to range quite a bit among the PEM, PSS and PFO Cowardin classes. In the emergent areas they ranged from 24 percent to 100 percent. Among the PSS classes the ratio ranged from 18 percent to 68 percent. In the PFO classes, the percent of FACW and obligate species showed the least variation ranging from 15 percent to 47 percent. The performance standards are derived from the averages for each Cowardin class observed among 24 wetlands.

Table 17. Distribution of different plant associations within a wetland.					
Wetland	BOG Percent of Total that are FACW and Obligate Species	PEM Percent of Total that are FACW and Obligate Species	PFO Percent of Total that are FACW and Obligate Species	PAB Percent of Total that are FACW and Obligate Species	PSS Percent of Total that are FACW and Obligate Species
AL3			0.28		0.26
B3I		0.38	0.36		0.43
BBC24		0.57	0.25		
CL	0.62	0.38			0.48
EC21			0.33		0.21
EC28		0.57			0.40
EC29		1.00			0.29
ELS34	0.50		0.15	1.00	0.33
ELS39		0.29	0.24		0.45
ELS61		0.56		1.00	0.47
ELW1			0.33		0.43
FC1		0.29	0.40		0.42
HC13			0.17	0.80	0.54
JC28		0.43	0.33		0.68
LCR93					0.65
LPS9		0.86	0.33		0.46
MGR36		0.63	0.26	0.88	0.51
NFIC12			0.24		0.18
PC12		0.70	0.24		0.23
RR5		0.60	0.47		0.56
SC4			0.24		0.50
SC84		0.56	0.33		0.48
SR24		0.64	0.34	1.00	0.52
TC13		0.24	0.24		0.34
Average among all wetlands	0.56	0.54	0.29	0.94	0.43

Methods: Species were categorized according to their wetland dependency using the National List of Plant Species that Occur in Wetland: Northwest (Region 9) (Reed 1988, and Reed 1993). The percentages of FACW and obligate species were compared with the percentages of FAC, FACU and upland species within each Cowardin habitat class and the ratios determined. These percentages were then averaged across all similar habitat classes for all the wetlands.

Definition: The number of dominants (comprising >10% cover of overall wetland plant species)

Reference Standard:

Class (Cowardin)	Cover
PEM	14-75%
PSS	20-48%
PFO	22-67%
PAB	17-80%
BOG	63-69%

Project Performance Standard: Limit the number of dominant plant species present (dominant defined as >10% cover over the entire wetland) to not more than 50% of the total number of species within each Cowardin class with the exception of the aquatic bed class (PAB) which may range up to 80% of the total species.

Achievement of this performance standard may be demonstrated by vegetation survey data identifying the number and coverage of dominant species relative to the number and coverage of subdominant and rare species.

Related HGM Variables: *Vpdomin*

Related HGM Functions: Plant Communities

Rational: Vegetation communities are often identified by the dominant vegetation observed in them. This standard derives from the concept that the more variety of dominant species observed, the greater the diversity of habitats likely present. However, subdominant and rare species are also critical components of wetland diversity, so it is important to balance the ratio of dominants, subdominants and rare species.

On average the percentage of dominant species was between 35 and 45 percent in all the Cowardin classes for all the wetlands analyzed for this study with the exception of bogs. Plant dominance in individual wetlands ranged from a low of 14% to as high as 75 percent of the total, both observed in emergent communities. Virtually all measures of dominance were less than 50% of the plant community among all the wetlands studied. The performance standard is based on the maximum average observed among the PEM, PSS and PFO Cowardin classes and the maximum observed in the PAB class.

Table 18. Percent of species dominant (>10% coverage) in Cowardin habitat classes.					
	Percent of all species that are dominant				
Wetland ID	BOG	PEM	PFO	PAB	PSS
AL3			0.30		0.26
B3I		0.54	0.36		0.36
BBC24		0.36	0.33		
CL	0.69	0.55			0.31
EC21			0.34		0.29
EC28		0.23	0.38		0.20
EC29		0.75			0.32
ELS34	0.63		0.60	0.17	0.48
ELS39		0.14	0.30		0.39
ELS61		0.41		0.80	0.29
ELW1			0.67		0.33
FC1		0.50	0.34		0.30
HC13			0.22	0.40	0.31
JC28		0.29	0.40		0.44
LCR93					0.35
LPS9		0.29	0.35		0.36
MGR36		0.37	0.26	0.50	0.43
NFIC12			0.35		0.45
PC12		0.37	0.33		0.26
RR5		0.31	0.29		0.41
SC4			0.26		0.40
SC84		0.39	0.46		0.36
SR24		0.42	0.24	0.33	0.32
TC13		0.38	0.41		0.34
Average for all wetlands	0.66	0.39	0.36	0.44	0.35

Methods: All species with greater than 10 percent coverage in plots and covering greater than 10 percent of the plots surveyed were identified as dominant species. These species were tabulated in relationship to subdominant species and the relative ratio determined for all separate Cowardin classes in each wetland. The results were then averaged for each Cowardin class among all wetlands.

Definition: The vertical structure and linear characteristics of the wetland/upland edge.

Reference Range: Gradients ranged from 0 - 10%

Project Performance Standard: The water land edge should be gradually sloping (not exceeding 10%) with a high length of shoreline to area ratio (>1.5).

This can be demonstrated through the preparation of an "as-built" topographic survey and cross-section.

Related HGM Variables: *Vedgestruc*

Related HGM Functions: Amphibian Habitat, Bird Habitat, Aquatic Fur-bearing Mammals, Invertebrate Habitat

Rational: Wetland fauna is intimately tied to wetland edge structure in that wetland bathymetry is the dominant physical feature influencing water depth. Optimum water depths in sufficient quantities (i.e., minimum area or percentage of total wetland area) influences the distribution and abundance of aquatic fauna and the vegetation required for breeding, rearing, and feeding. The characteristics of vegetation also modify competition and predator-prey relationships. In general, the density of aquatic invertebrates as well as vertebrates including many amphibians, reptiles, birds and mammals are highest in shallow to mid-depth water. Hence wetlands with large areas of gentle slopes and, or shallow water shelves provide the highest potential habitat quality.

Transects measuring the wetland to water slope ranged from one to 10 % among three wetlands that were measured. The length of shoreline was not measured however, a high length of shoreline to total area ratio increases the potential for water edge habitat.

Methods: The slope of the wetland upland edge was measured by surveying the depth of water in three wetlands with average or better plant and animal richness. Transects were located from upland to upland crossing the wetland to obtain a profile of water depth in relationship to the distance from the upland. Transects were located so as to cross areas of obvious topographic change. Slopes were calculated based on the data obtained.

5.10. *Flow*

Definition: The velocity of surface water.

Reference Standard: < 5cm/sec (0.15 ft./sec.)

Project Performance Standard: Flow velocity of wetland waters should be minimized to the extent possible. This can be demonstrated by the design features that determine the shape and configuration of the wetland. The following are suggestions for minimizing flow velocity. Demonstrated performance for this variable should address the following four factors.

1. Inlet configuration effect on flow velocity:

   Guidance:

   a. Have water enter the wetland in a relatively wide inlet to distribute the flow and slow it down.

   b. Have the water enter into a deep pool at the inlet.

2. Creation of backwater areas:

   Guidance:

   Maximize the interface between land and water (interspersion rating). Wetlands should have an interspersion rating of 8 or greater meaning that the land to water boundaries should be sinuous with 25%to 75% open water or curvilinear and with between 6% and 95% open water. (see Figure 8: Land and Water Interspersion diagrams for examples, Page 73).

Related HGM Variables: NA

Related HGM Functions: NA

Rational: Flow velocities in wetlands should be minimized to the extent possible so as to provide some areas of slow water suitable for use by a diversity of wetland species that require quiescent waters for breeding and feeding. Studies of amphibians have shown that for successful breeding to occur, water velocities should be dominated by flows less than 5cm/sec (0.15 ft./sec).

Methods: The methods and results of this study are available in Richter and Azous (1993).

Definition: Fluctuation refers to mean annual water level fluctuation (WLF) which is defined as the difference between the maximum water level reached in an interval of time, no longer than one month in length) and the average base water level (the average during periods in the interval unaffected by storm events) averaged over a year.

Reference Standard: Varied from 3 to 46 cm (0.09 to 1.54 ft.).

Project Performance Standard: Limit mean annual water level fluctuation (WLF) to 21 cm (8.4 inches) annually.

Water level fluctuation for each month is calculated as follows:

- WLF (monthly) = Maximum stage - Average base stage
- Average base stage = (Instantaneous stage at beginning of interval + Instantaneous stage at end of interval)/2

Mean annual WLF is calculated as the monthly WLF averaged over one year.

The following design guidance should be used to minimizing the inter storm water level fluctuations:

1. Limit mean water level fluctuation (WLF) to 0.2 M annually. WLF is defined as the difference between the maximum water level reached in an interval of time, no longer than one month in length) and the average base water level (the average during periods in the interval unaffected by storm events).

2. The wetlands can also be designed so that infiltration and evaporation will dry out the dead storage volume for one to four weeks in most summers.

3. The design of the proposed depressional flow-through wetland could be modeled with HSPF or equivalent methodology to assess predicted water level fluctuations.

Achievement of goals for minimizing water level fluctuations can be demonstrated after the wetland is constructed showing a minimum of two years of monitoring wetland maximum, minimum, and time of visit water levels monitored monthly. Alternatively, water levels and rainfall, using an on-site rainfall gauge, may be monitored for one year and a statistical analysis performed on the data. The analysis should show the potential variation in seasonal water levels based on the monitored year in relationship to historical rainfall maximums and minimums obtained from a nearby official rainfall gauging station.

The average water level fluctuations can be calculated and the maximum, minimum, and time of visit water levels plotted versus time. This information will be used to determine the actual water level fluctuation regime achieved by the created wetland. If this water level regime is

within the design goal, the wetland will meet the standard.

Related HGM Variables: NA

Related HGM Functions: NA

Rational: In the Pacific Northwest, wetlands with damped water level fluctuations tend to have the highest richness of plants and animals . The research has shown that wetlands that have experienced spring growing and breeding season water level fluctuations exceeding 21 cm (8.4 inches) have less diverse plant and animal communities. Consequently, a design goal for wetland mitigation is to control water level fluctuations between storms in wetland areas designed for habitat functions.

Table 19. Wetland watershed, outlet and hydrologic characteristics.

Wetland Name	Forest (%)	Imperv. Area (%)	Outlet Constr.	Range of Water Depth (m)	Mean WLF (m)	Max. WLF (m)	Mean Dry Period (days)	Calculated Mean WLF (m) Using Multiple Regression
AL3	73.9	3.4	1	0.00-0.62	0.07	0.31	101	0.21
MGR36	88.8	2.7	0	0.13-0.74	0.07	0.26	0	0.08
JC28	34.4	19.3	0	0.00-0.32	0.08	0.17	74	0.14
RR5	62.4	3.2	0	0.02-0.52	0.09	0.24	0	0.11
SC4	46.1	11.8	0	0.00-0.30	0.10	0.15	125	0.13
SR24	100.0	2.0	0	0.00-0.67	0.11	0.23	32	0.07
NFIC12	100.0	2.0	1	0.00-0.53	0.13	0.30	189	0.17
ELS61	0.0	3.9	0	0.05-0.84	0.14	0.33	0	0.19
PC12	75.2	3.9	1	0.20-1.19	0.14	0.84	0	0.20
BBC24	89.5	2.8	0	0.07-0.60	0.14	0.20	0	0.08
TC13	100.0	2.0	0	0.00-0.72	0.16	0.31	156	0.07
ELW1	0.0	19.9	0	0.00-0.66	0.22	0.44	19	0.19
HC13	76.6	3.6	1	0.09-1.56	0.24	0.41	0	0.20
SC84	20.1	15.9	0	0.00-1.08	0.26	0.53	62	0.16
FC1	14.7	30.8	0	0.11-1.01	0.28	0.62	0	0.38
LCR93	44.1	3.9	1	0.00-0.81	0.28	0.57	61	0.24
ELS39	0.0	28.0	1	0.00-1.61	0.46	1.29	151	0.51
B3I	0.0	54.9	1	0.63-2.37	0.57	1.54	0	0.51
LPS9	0.0	21.8	1	0.00-1.72	0.60	1.47	85	0.51

Methods: Water depths were measured approximately nine times per year in 19 wetlands for four to five discontinuous years over a ten year period. The maximum for the period and the depth on the sampling date were used to generate hydrographic statistics including WLF. Water depths and fluctuations were statistically related to plant, amphibian, mammal and bird communities which showed reduced richness among plants and amphibians.

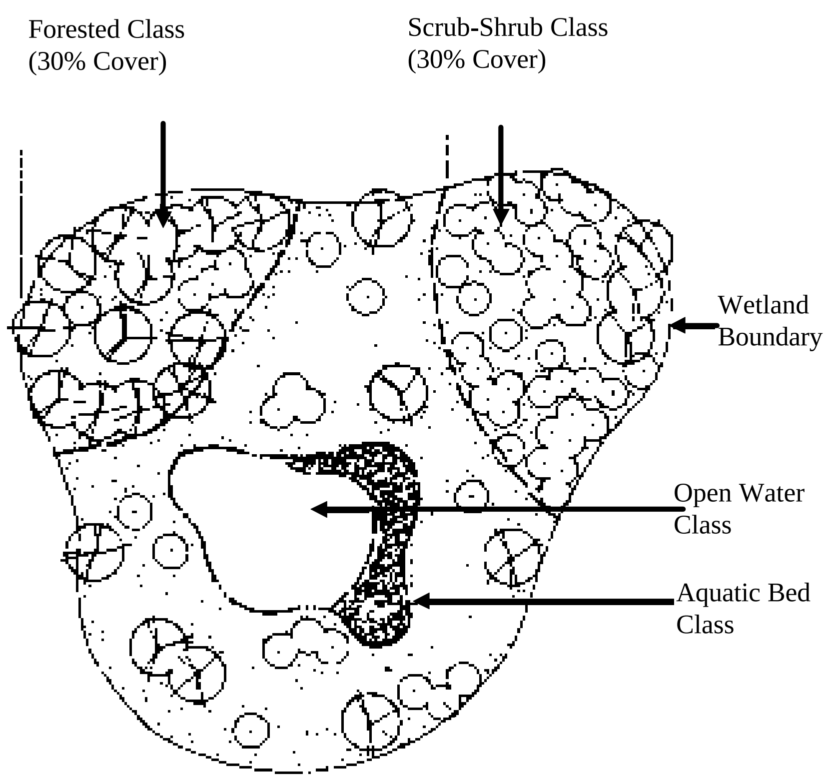
Definition: The number of distinct habitat classes in each wetland community (PFO, PSS, PEM, PAB) as per Cowardin et. al., 1979.

Reference Standard: 2-4 habitat classes

Project Performance Standards: The number of distinct habitat classes in the wetland should equal or exceed three.

This performance standard is achieved when aerial photographs or transects across the wetland identify three habitat classes within five years.

Figure 5. Determining Habitat Classes

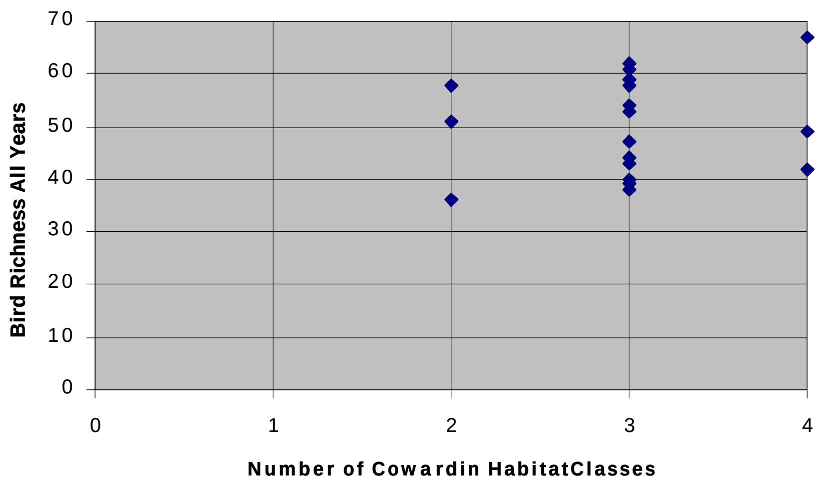


Related HGM Variables: *Vhabitatclasses*

Related HGM Functions: General Habitat, Plant Communities, Bird Habitat

Rational: Biodiversity can be inferred from the number of habitat classes (as per Cowardin et al. (1979)) in a wetland. For certain functions (e.g., Plant Community, Bird Habitat) habitat classes increase species richness. Specifically, wetlands with three or more habitat classes rank significantly higher in plant richness than those wetlands with two or fewer habitat classes (Mann-Whitney, $p = 0.03$, $U' = 64.5$). Similarly, wetlands with three or more habitat classes also provide habitat for birds than those with fewer classes (Figure 6).

Figure 6. Bird richness related to the number of habitat classes as per Cowardin et al. (1979).



Methods: Transects were located within the study wetlands in order to cross the all the vegetation zones comprising the wetlands. Sample plots were established along the transect line in areas of homogeneous community types and in areas where the vegetation was in transition between community types. The types of species present in the plot were identified and their coverage were estimated using an octave scale for classification. Based on the data collected the plot was assigned a community type for the Cowardin system. The number of distinct Cowardin zones identified in each wetland was then tabulated and statistically related to plant, amphibian, bird and mammal richness using parametric tests.

5.13. *Herbs*

Definition: The percentage of the wetland area that has persistent emergent plant cover.

Reference Standard: Less than 10% to 50-80%.

Project Performance Standard: Wetlands designed to support mammal habitat should have 30% to 50% of the total area planted with herbs.

Related HGM Variables: *Vherb*

Rational: Persistent emergent plants provide a variety of plant materials for feeding, hiding and nesting materials for small mammals and birds. Herb coverage in the wetlands we measured was categorized into broad classes (shown in Table 20) and varied between the categories of less than 10% up to 50 to 80%. The standard is based on the wetlands with the highest functioning mammal communities (shown in the shaded bars).

Methods: Herb coverage was determined by examining aerial photos of each wetland and measuring the aerial coverage of emergent zones as compared with other zones. Wetlands were classified into the broad categories shown in Table 20.

Table 20. Herb Cover

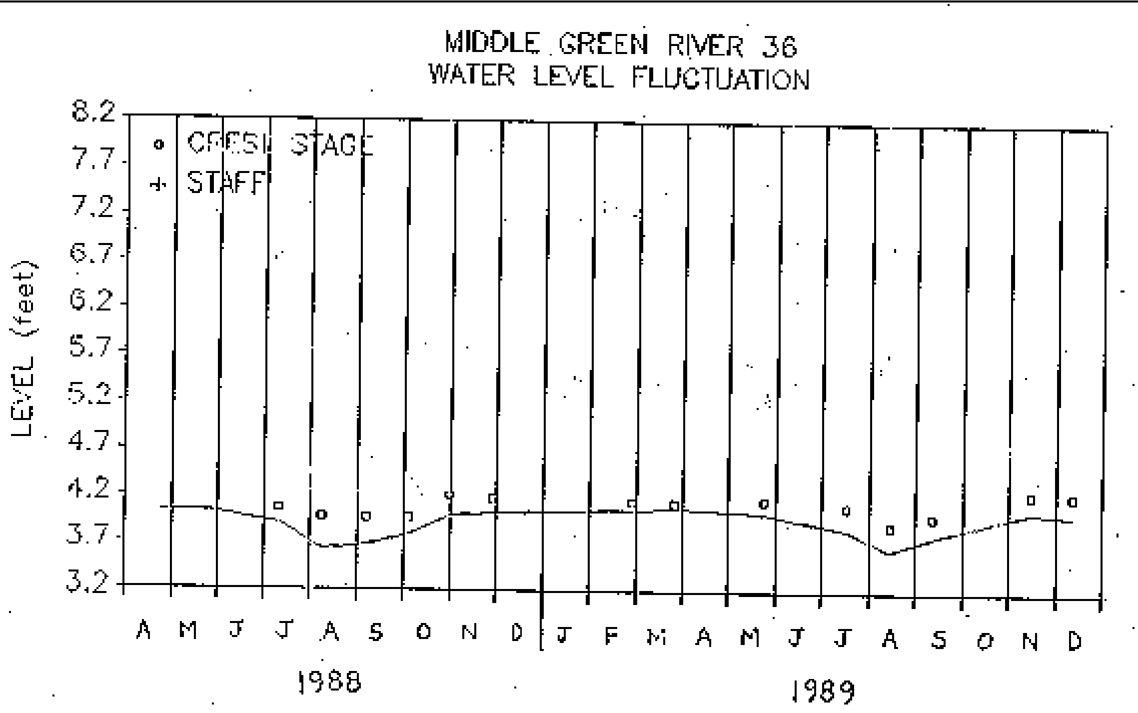
Wetland ID	herb coverage in wetland
AL3	<10%
B3I	<10%
BBC24	50-80%
ELS39	30-50%
ELS61	30-50%
ELW1	<10%
FC1	50-80%
HC13	<10%
JC28	10-30%
LCR93	30-50%
LPS9	10-30%
MGR36	30-50%
NFIC12	<10%
PC12	30-50%
RR5	30-50%
SC4	<10%
SC84	<10%
SR24	50-80%
TC13	10-30%

Definition: The periodicity and duration of water in the wetland.

Reference Standard: Stable base hydrograph with low storm event fluctuations to fluctuating base hydrograph with high event fluctuations.

Project Performance Standard: The wetland hydroperiod should have a stable (permanent) or low fluctuating (seasonal) base hydrograph with infrequent storm event fluctuations (Table 21).

Table 21. Hydrograph of wetland with stable base water level and low event fluctuations.



The applicant shall provide written design goals describing wetland hydroperiod based on analysis using HSPF or equivalent methodology. Goals should state the expected average frequency of excursions greater than 15 cm above or below the mean water level and should predict the duration of such excursions for a normal water year.

Achievement of these goals may be demonstrated by two years of supporting data showing continuous water level monitoring provided the water years are within normal precipitation volumes and events. Alternatively, water levels and rainfall, using an on-site rainfall gauge, may be monitored for one year and a statistical analysis performed on the data. The analysis should show the potential variation in hydroperiod based on the monitored year in relationship to historical rainfall obtained from a nearby official rainfall gauging station.

To determine if your water years are normal (for low land areas in Central Puget Sound Basin), the following suggestions may provide guidance:

- A storm event may be defined as: precipitation event accumulating equal to or greater than 1.00 inches of precipitation with no gaps of rain equal to or greater than 6 hours (Hence, an accumulation equal to or greater than 1.00 inch of rain and a gap with no rain equal to or greater than 6 hours defines the end of an event).
- Normal frequency of these storm events occurs on average eight +/- three times a year.
- Mean annual precipitation with a standard error (e.g. SEATAC equals 39 +/- 7 inches per year)
- Dry years may be determined either by the lack of storm events or the less than average annual precipitation

The following design guidance may be helpful in formulating goals for wetland hydroperiod:

- Limit the frequency of stage excursions greater than 15 cm (6 inches) above or below the mean water level (non-storm event based) to six or less (on average) per year. Multiple years may be used for estimating the average frequency of excursions per year.
- Limit the duration of stage excursions greater than 15 cm (6 inches) above or below the mean water level to no more than 72 hours per excursion.
- During the amphibian breeding season, February 1 through May 31, limit the magnitude of stage excursions above or below the average base water level to no more than 8 cm (3 inches), and limit the total duration of these excursions to no more than 24 hours in any 30 day period.

<u>Related HGM Variable</u>: *Vhydrop*

<u>Related HGM Functions</u>: General Habitat, Invertebrate Habitat

<u>Rational</u>: The periodicity and duration of water in the wetland is a major determiner of the floral and faunal communities in a wetland as many species are linked to particular depths and ranges of water levels. In general, in the Puget Sound Basin, more species of plants and animals are found in wetlands with water regimes that may or may not vary seasonally but which have relatively low event fluctuations. Therefore wetland hydroperiod standards require that wetlands be designed to maintain stable (permanent) or fluctuating base (seasonal) flows with low event water level fluctuations. This guideline is especially important during the growing season (Feb. 1 to Sept. 30) and amphibian breeding season (Feb. 1 to May 31).

Methods: Continuous recording gages were installed in six wetlands in late 1994 and early 1995. The gages were programmed to record water surface elevations at 15-minute increments. Two of the wetlands monitored were in relatively undisturbed watersheds and were already experimental controls in an ongoing study. The remaining four were selected as they were known to experience large changes in water depth throughout the year.

Water levels in all six wetlands were monitored over one year, however due to unexpected seasonable differences in rainfall and some losses of data due to malfunctioning equipment, there was only a partial water year for all the wetlands. The hydroperiod data was used to

calibrate the computer model Hydrologic Simulation Program- FORTRAN (HSPF), a continuous event model with the ability to simulate hydrologic processes in a watershed. The model is used to predict rainfall runoff from different watershed conditions and is more accurate when field measurements are used to adjust runoff from simulated rainfall events with the outflows and stages resulting from actual events.

The condition of plant and amphibian communities were compared with the observed and predicted water depths, the duration of storm events and the frequency of storm events for the whole season and the early growing season (March 1 through May 15). . We analyzed the emergent, scrub-shrub and forested zones to determine if there were significant differences in community composition related to hydroperiod regimes .

Much of the data was categorized to provide more statistical rigor given the small data set and the 0.5 ft. (15 cm.) margin of error. Categories were based on frequency distributions of the data and a very limited sensitivity analysis of statistically significant breaks in the data. We measured frequency of storm events in a hydroperiod by defining an event as an excursion which was a water level depth increase of more than 0.5 ft. (15 cm.) above the monthly average. Duration was defined as the time period of an excursion. In a stepwise regression, we looked at the statistical relationship between WLF, frequency and duration. The detailed results of this study can be found in Chapter 13 of Azous et al. (1997).

Definition: Infiltration rate of soil.

Reference Standard: Glacial till, lacustrine silts or clays, or bedrock with an infiltration rate or saturated permeability of less than 1 x 10-6 m/s or 0.14 inches per hour will underlie the wetland.

Project Performance Standard: Demonstrating either of the following conditions will be evidence of a suitable wetland substrate:

1. The proposed wetland can be excavated to within 1 foot of the water table as measured any time between April 1 to June 30 with the goal of supporting habitat functions and the excavated water depths monitored. Maximum, minimum, and time of visit water levels monitored monthly using a continuous recording level gauge, shallow well piezometer, the Richter (1997) maximum and minimum water level recording device or equivalent will demonstrate the seasonal presence of water.

2. At least 4 feet of glacial till, lacustrine silts or clays, or bedrock with an infiltration rate or saturated permeability of less than 1 x 10-6 m/s or 0.14 inches per hour will underlie the wetland.

3. If the natural geologic conditions do not meet these criteria, a liner with a permeability less than or equal to 1 x 10-6 m/s or 0.14 inches per hour should be included in the design.

Demonstration that these standards have been met can be performed using infiltration tests such as a ‘packer’ test.

Related HGM Variable: *Vsubconnect* (NRCS drainage class of soil)

Related HGM Functions: Maintain Seasonal Low Flows

Rational: Creating a depressional wetland in the climate of King County depends on having a low permeability wetland base. Incidental rainfall will generally provide sufficient rainfall for wetland conditions if a suitable wetland bottom exists. The abundance of natural wetlands on flat topography based on low-permeability till with little additional contributing area is evidence of this design concept. Other examples of this concept are the low-quality wetlands that form on top of landfill covers after the refuse settles and creates flat areas. Therefore, the first step in designing a depressional wetland is to assess the underlying stratigraphy, its infiltration characteristics, and the location of the water table.

Methods: Standard is based on current engineering practices and best professional judgment.

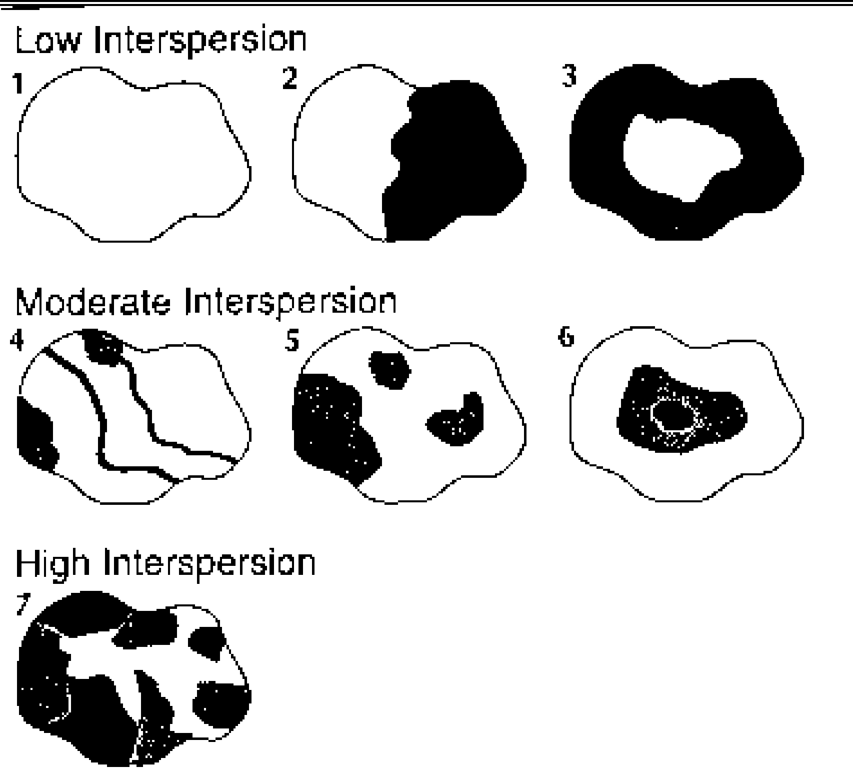
Definition: The amount of interspersion present between Cowardin vegetated classes.

Reference Standard: Ranged from 3 - 7 (based on the Oregon Freshwater Assessment Methodology).

Project Performance Standard: Wetland should have at least a moderate vegetation interspersion rating equal to or greater than six. A moderate interspersion rating is one that has at least two wetland classes and an upland class with a complex pattern of interspersion. Figure 7. Vegetation Interspersion should be used to evaluate the pattern of interspersion.

This standard can be demonstrated by using aerial photos for comparison purposes.

Figure 7. Vegetation Interspersion



Related HGM Variable: *Vvegintersp*

Related HGM Function: General Habitat Function, Aquatic Fur Bearing

Rational: The interspersion of different vegetation classes is an indicator of habitat complexity. More edges between different plant communities support a greater diversity of wildlife, particularly bird species.

Interspersion ratings among the wetlands surveyed ranged from three to seven but were six or greater in the high biodiversity wetlands (shaded), which serve as the basis for the standard.

Table 22. Range of vegetation interspersion ratings found in surveyed wetlands.

Wetland	Oregon Interspersion Rating of Cowardin Classes	Ranking
AL3	3	low
B3I	7	high
BBC24	6	moderate
ELS39	4	moderate
ELS61	6	moderate
ELW1	4	moderate
FC1	7	high
HC13	3	low
JC28	4	moderate
LCR93	7	high
LPS9	3	low
MGR36	7	high
NFIC12	3	low
PC12	7	high
RR5	6	moderate
SC4	5	moderate
SC84	4	moderate
SR24	7	high
TC13	6	moderate

Methods: Interspersion was determined based on aerial photo analysis and the number of Cowardin habitat classes reported for the wetland. The following criteria were used to determine interspersion class:

- Low interspersion = Wetlands with only one wetland class or with two wetland classes and a simple pattern.
- Moderate Interspersion - Wetlands and upland complexes that have at least two wetland classes and a complex pattern.
- High Interspersion - Wetlands with two or more wetland classes or upland inclusions with a complex pattern and lots of edge.

Definition: The amount of interspersion present between portions of wetland and open water (based on Oregon Freshwater Assessment Methodology).

Reference Standard: Ranged from 4 - 10.

Project Performance Standard: The wetland site design should show that the wetland has an interspersion ≥ 8. This means that the land to water interface should be sinuous with 25%to 75% open water or curvilinear and with between 6% and 95% open water.

Related HGM Variables: *Vl/wintersp*

Related HGM Functions: General Habitat Function, Aquatic Fur Bearing Mammal Habitat

Rational: The mosaic of land and water within a wetland provide habitat complexity for many species. Highly sinuous land and water boundaries and low water velocities furnish a diversity of a land-water ecotones that provide habitat for terrestrial and aquatic species.

Land and water interspersion ratings ranged from 2 to 10 among the 19 wetlands surveyed. The combinations of the percent of open water and the condition of the land to water edge comprising each land-water interspersion ranking are shown in Table 23. Our data shows that the wetlands with the highest functions for biodiversity (shaded) had rankings of eight or greater and are the basis for the performance standard.

Figure 8: Land Water Interspersion

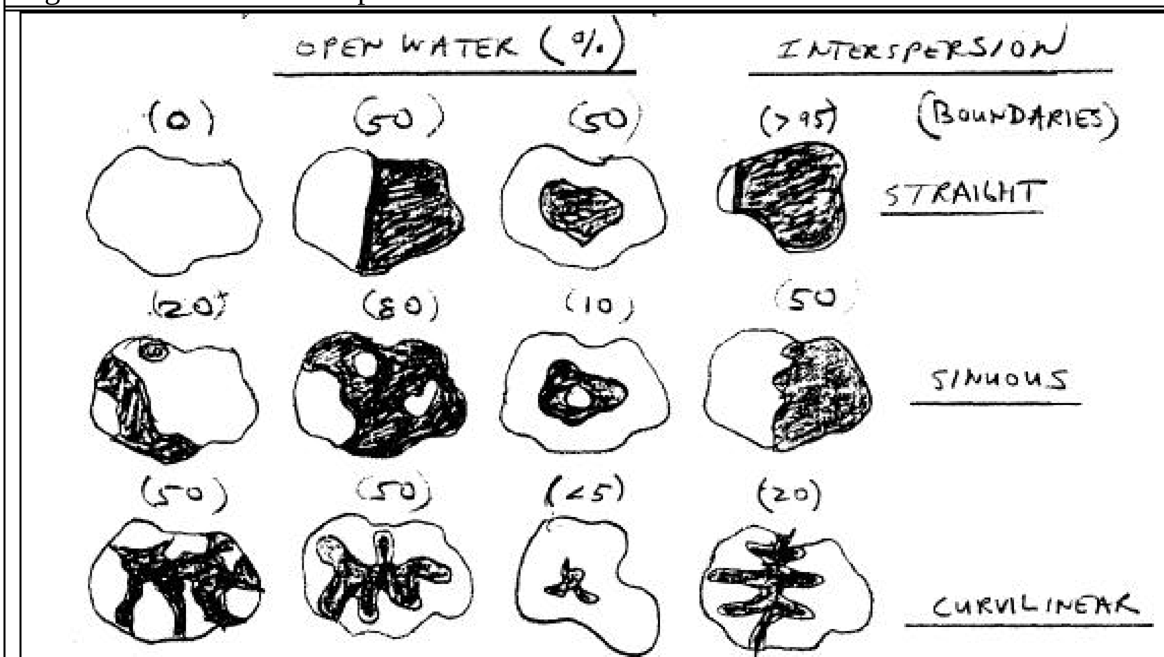


Table 23: Range of land and water interspersion ratings found in 19 wetlands (bolded wetlands are used to identify preferred performance standard).			
Wetland	Land and Water Interspersion Rating	Percent of Open Water	Land to Water Edge
AL3	4	<5%	sinuous
B3I	8	6-24%	curvilinear
BBC24	**10**	**25% to 75%**	**curvilinear**
ELS39	4	<5%	curvilinear
ELS61	8	25-75%	sinuous
ELW1	4	<5%	sinuous
FC1	4	<5%	sinuous
HC13	2	<5%	straight
JC28	4	<5%	sinuous
LCR93	4	<5%	sinuous
LPS9	4	6-24%	straight
MGR36	6	6-24%	sinuous
NFIC12	4	<5%	straight
PC12	**8**	**6-24%**	**curvilinear**
RR5	**8**	**25% to 75%**	**sinuous**
SC4	4	<5%	sinuous
SC84	8	25% to 75%	sinuous
SR24	**10**	**25% to 75%**	**curvilinear**
TC13	4	<5%	sinuous

Methods: Land and water interspersion was determined based on aerial photo analysis comparing the wetland with the diagrams shown in Figure 8. in conjunction with an estimate of the percent of open water observed in the wetlands. These data were used to rank the level of interspersion between land and water in the wetland using the matrix shown in Table 24.

Table 24. Land Water Interspersion Ranking					
	Percent of Open Water				
Edge Condition	< 5%	6-24%	25-75%	76-95%	>95%
straight	2	4	6	4	2
sinuous	4	6	8	6	4
curvilinear	4	8	10	8	4

Definition: The percent cover of non-native species present in the wetland.

Reference Standard: Ranged from 0 - 7 species and from no presence to dominating 67% of the vegetation sampling plots.

Project Performance Standard: The percent of area covered by invasive species should not exceed 15% of the wetland or 0.5 acre of contiguous coverage, whichever is greater, and, if exceeded, appropriate control procedures should be implemented.

Achievement of this standard may be demonstrated by annual field survey data that identify the invasive members of the plant communities present and measures their coverage within the wetland.

Related HGM Variables: *Vnonative*

Related HGM Functions: Plant Communities

Rational: Many non-native species are aggressive competitors among our native plant associations. Some native plant species are also invasive. When invasive species begin to dominate a plant community the effect is reduced species diversity and, as a consequence, reduced function to support habitat. With fewer species present there are fewer habitat niches, reduced numbers of strata and simpler community structures. This reduces the resiliency of a wetland to respond to disturbance conditions and overall, depresses biodiversity. Therefore, it is important to control the spread and numbers of invasive species to the maximum extent possible.

Stations dominated by invasive plants ranged from zero to 67% of the total sample stations surveyed depending on the wetlands. The average number of sample stations dominated by invasive plants was 20% among all wetlands. This was considered too high for practical application. It is critical to deal with invasive plants early once observed in wetlands because after introduction, they typically outperform other species particularly when land has been disturbed. The standard is based on the ranges found among wetlands with highly functional biological communities (shown in shaded bars).

Methods: The nineteen wetlands were surveyed to determine the numbers of invasive species present. The total numbers observed among all wetland plant associations ranged from zero to the maximum of seven possible. Table 25 shows the species we identified as invasive and which wetlands they were observed in.

We also examined non-native species distribution by evaluating species dominance within each sample station. Sample stations with invasive species comprising greater than 32% of the plot were classified as dominated by invasive plants. Then the number of plots dominated by non-

native species was compared with the total. The percent of non-native dominance among plots was used as an indicator of the percent of wetland area dominated by non-native species.

Table 25. Invasive species presence and distribution

	Invasive Herbs			Invasive Rushes		Invasive Shrubs					
Wtld	PHAL ARUN	RANU REPE	SOLA DULC	JUNC EFFU	JUNC ENSI	RUBU LACI	RUBU PROC	Number of weed species observed in wetland	Total Sample Stations	Number of Sample Stations Weeds >32% Coverage	Percent of Sample Stations Weeds Were Dominant
AL3			X			X		2	12	0	0%
B3I	X		X	X		X	X	5	18	12	67%
BBC24	X	X	X	X	X	X		6	19	1	5%
ELS39	X	X	X	X		X	X	6	9	1	11%
ELS61	X	X	X	X		X	X	6	15	2	13%
ELW1	X		X				X	3	7	1	14%
FC1	X	X	X			X	X	5	15	10	67%
HC13	X	X	X			X		4	13	1	8%
JC28	X	X	X	X		X		5	19	6	32%
LCR93		X				X	X	3	11	0	0%
LPS9	X	X	X	X		X		5	25	5	20%
MGR36	X	X	X	X		X	X	6	16	5	31%
NFIC12			X					1	17	0	0%
PC12	X	X	X	X	X	X	X	7	20	13	65%
RR5	X	X	X	X	X	X	X	7	16	1	6%
SC4	X	X	X		X	X	X	6	14	0	0%
SC84	X	X	X		X	X	X	6	28	12	43%
SR24	X	X	X	X	X	X	X	7	31	4	13%
TC13			X	X		X		3	11	0	0%
Average among all wetlands											20%

Definition: The presence or absence of open, unshaded, permanent open water that is more than 1/4 acre in size (>1,000 m^2) or more than 10% of the wetland, whichever is smaller.

Reference Standards: Nine out of 19 wetlands had at least 1,000 m^2 (0.25 acres) of open water.

Project Performance Standard: There should be a minimum of 1,000 m^2 (0.25 acres) of open water available within the wetland.

This can be verified by measuring the area of open water using aerial photos.

Related HGM Variables: *Vopenwater*

Related HGM Functions: Bird Habitat

Rational: Open water provides habitat and foraging habitat for a variety of avian and aquatic species. The water should be present through the spring breeding season (March - June) to provide the maximum benefit.

Nine out of nineteen wetlands we measured had at least 1000 m^2 (0.25 acres) of open water. Each of the four wetlands with the highest measurements of species richness had areas of open water greater than 1000 m^2.

Methods: The presence and coverage of open water within each wetland was estimated from aerial photographs. Wetlands with and without open water were compared with plant and animal diversity. The four highest ranking wetlands for plant and animal richness all had open water areas greater than 1000 $m.^2$

Definition: The solar orientation of the wetland perimeter.

Reference Standard: 98% of amphibian eggs were on the north shore, with 68% of these along the northwestern shore.

Project Performance Standard: Maximize solar exposure and opportunity for amphibian breeding by establishing gradual (i.e.: 10:1) slopes in the northwestern quadrants of wetlands.

Related HGM Variables: NA

Related HGM Functions: NA

Rational: Pacific Northwest amphibians show a clear preference for northern quadrants of wetlands, although the importance of orientation decreases with wetlands size.

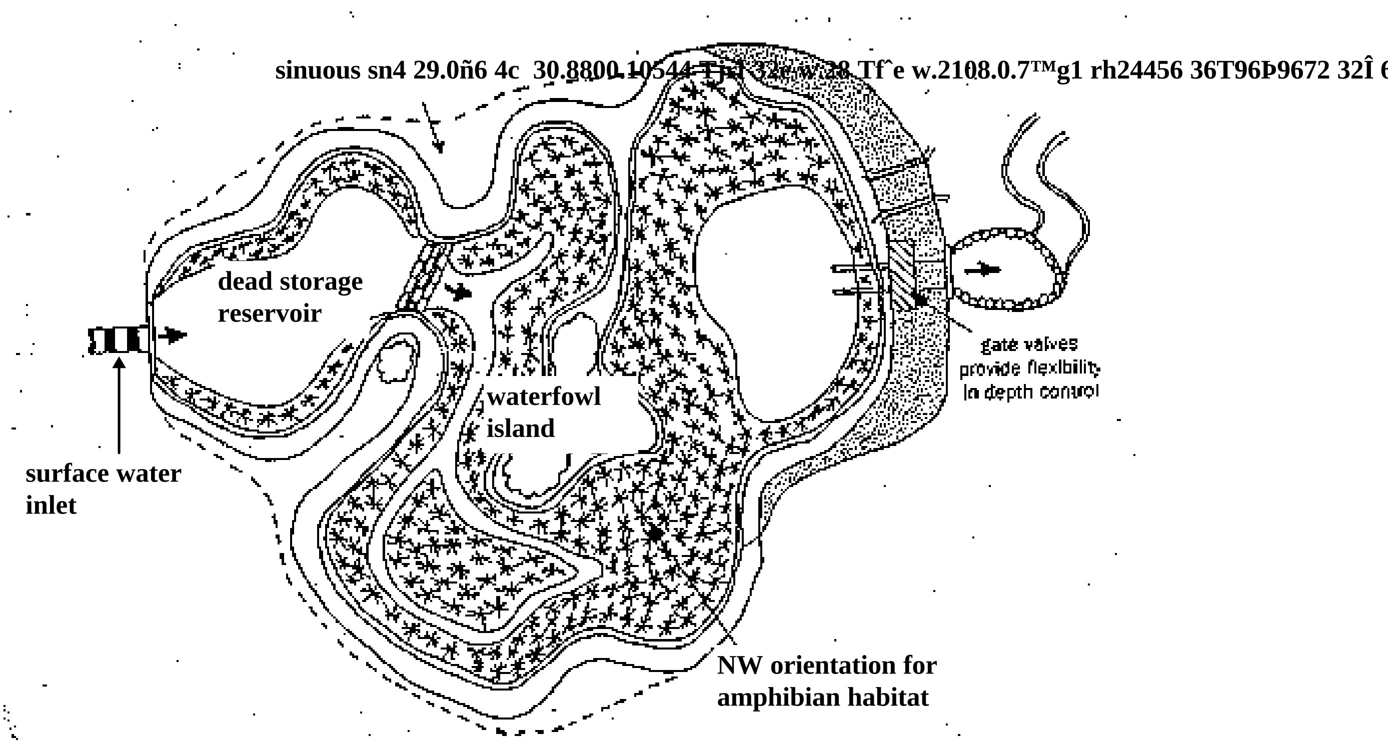
Methods: For methods see Richter (1995).

Definition: The amount of constriction in surface outflow from the wetland.

Reference Standard: Outlets varied from open channel to highly constricted. Outlet structures included culverts, open stream channels, beaver dams, roads, bulkheads and catch basins.

Project Performance Standard: The outlet control should approximate a low beaver dam; either acting as a broad-crested weir or as a leaky berm. Outlet effectiveness will be demonstrated by evidence of achieving hydroperiod and WLF design goals. This can be demonstrated by monitoring water levels and calculating mean annual water level fluctuation in the wetland. The outlet should be configured with sufficient downstream capacity to enable the outlet to operate as designed. A downstream analysis is also required to determine non-significant (DNS) impacts due to the outlet design.

Figure 9. "Typical" created wetland design



control approximate a low beaver dam; either acting as a broad crested weir or as a leaky berm. It is important to minimize inter-storm water level fluctuation in wetland creation and the outlet control structure is key to managing wetland hydroperiod.

Table 26. Wetland and watershed morphologic and hydrologic characteristics.

Wetland	Outlet Condition	Outlet Constriction	WLF Type	Dry in Summer?	System Type	% TIA 1989	% TIA 1995
AL3	None	high	FL	Y	OW/D	4	4
B3I	Culvert	high	SH	N	FT	55	55
BBC24	Beaver dam	low	SL	N	OW	3	11
ELS39	Culvert	high	FH	Y	OW	25	25
ELS61	Stream	low	FL	N	OW	5	11
ELW1	Lake	low	SH	N	FT	20	20
FC1	Beaver dam	moderate	S/FH	N	FT	31	31
HC13	Beaver dam	high	FL	N	OW	4	4
JC28	Stream	low	SL	Y	FT	20	21
LCR93	None	high	FH	Y	FT	6	6
LPS9	Drain inlet	high	FH	Y	FT	22	22
MGR36	Stream	low	SL	N	FT	3	3
NFIC12	None	high	FL	Y	OW/D	2	40
PC12	Beaver dam	high	FL	N	OW	5	7
RR5	Beaver dam	low	FL	N	OW	3	3
SR24	Road	low	FL	N	OW	2	2
SC4	Culvert	low	SL	Y	FT	12	12
SC84	Stream	low	FL	Y	OW	19	17
TC13	Drain inlet	moderate	FL	Y	OW	2	2

Methods: Wetland outlet structures were observed and reported. Outlet condition was related to WLF and other hydroperiod issues in Taylor (1993).

Definition: The distance of the wetland to the nearest body of fresh water (>20 acres).

Reference Standards: 1.04 to 3.9 km (0.51 to 2.42 mi.)

Project Performance Standard: Wetland should be located within 1.6 km (1 mile) of a freshwater lake of 20 acres or greater.

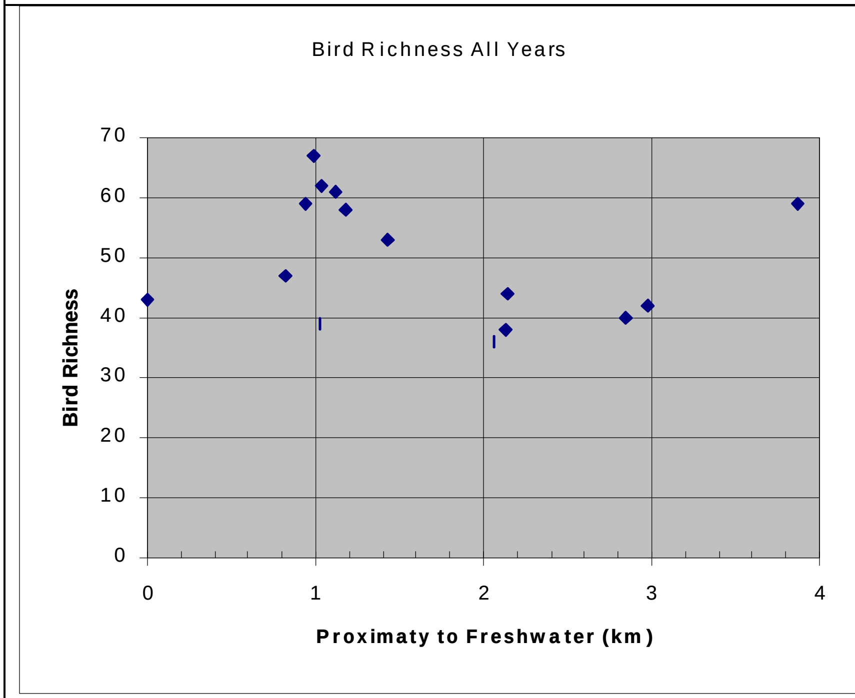
Map of wetland location showing proximity to nearest freshwater lake 20 acres or greater.

Related HGM Variables: *Vproxfresh*

Related HGM Functions: Bird Habitat

Rational: If there are larger bodies of water near the wetland more connectivity in the landscape is provided to support diverse populations of wetland birds. We compared the richness of the bird populations among 19 wetlands and found that the highest richness was observed in wetlands within 1.6 km of a freshwater lake at least 20 acres (8.3 ha) in size (Figure KS). Distances from the wetlands to the nearest large body of water ranged from 1.04 to 3.9 km (0.51 to 2.42 mi.).

Figure 10. Bird richness and proximity to freshwater.



Definition: The number of plant species present.

Reference Standards: 17 - 94 species

Project Performance Standard: Total species richness in a created wetland should equal or exceed 60 species.

Achievement of this performance standard may be demonstrated by showing field survey data which identifies the total plant species observed and calculating for both S (richness) and H' (Shannon and Weaver index).

Related HGM Variables: *Vprichness*

Related HGM Functions: Plant Communities

Rational: The number of plant species present in a wetland is a common measure of how effectively a wetland provides habitat and to what extent the wetland contributes to regional biodiversity. Wetland richness ranged from 17 to 94 species across all the wetlands surveyed, but averaged 60 species over all wetlands combined. The average of all wetlands was used as the basis for the standard.

Methods: Species were identified within each sample plot along all transects and the total number of unique species found within each wetland was calculated over all the study years. These totals were then averaged across all wetlands.

Table 27. Plant species richness	
Wetland	All Species Grand Total
AL3	64
B3I	68
BBC24	94
CL	65
EC21	58
EC28	48
EC29	35
ELS34	49
ELS39	62
ELS61	53
ELW1	41
FC1	64
HC13	38
JC28	67
LCR93	17
LPS9	68
MGR36	82
NFIC12	43
PC12	73
RR5	74
SC4	64
SC84	86
SR24	90
TC13	41
Average of All Wetlands	60.17

5.24. *Size*

Definition: Size of the wetland

Reference Standard: Wetland area ranged from 0.6 hectares - 11 hectares (1.5 to 27 acres).

Project Performance Standard: 1). Rural Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres). 2) Urban Wetland Standard: Wetland area should equal or exceed two hectares (about 5 acres) or, if smaller, should be connected to another natural habitat area.

This standard can be demonstrated by preparing surveyed wetland delineation maps.
Related HGM Variables: NA

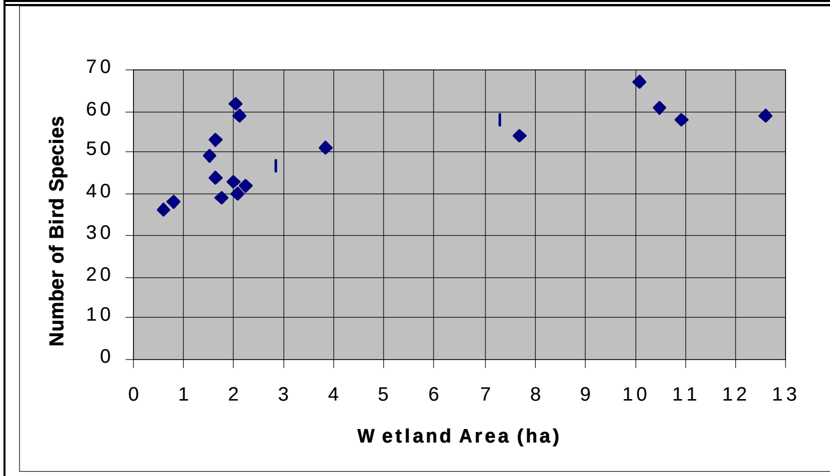
Related HGM Functions: NA

Rational: Wetland size is often used as an indicator for habitat function. Our studies have found that wetland size is significant to the richness of bird populations but is less critical to amphibian and mammal richness than other habitat parameters such as water depth fluctuation and the condition of adjacent habitat. The wetlands in our study ranged from 0.6 hectares (1.5 acres) to 11 hectares (27 acres) (Table 28).

Table 28. Table of wetland areas

Figure 11 shows bird richness related to wetland size. The data shows that all but one of the wetlands with at least 50% or more of the total number of species observed in all wetlands was at least 2 hectares or greater (5 acres). This data was used as the basis for the standard.

Figure 11. Bird richness related to wetland size



Methods: Wetland sizes were determined from GIS analysis. Bird richness surveys and studies are documented in Richter and Azous (1997b).

Definition: The maximum number of strata in any single plant association. [A plant association can have up to 5 strata (layers: trees, shrub, low shrub/liana, herb, moss). To count as a stratum, however, the plants of that stratum have to have 20% cover in the community in which it is found].

Reference Range: All wetlands had $\geq$ 3 strata.

Performance Standard: At least three strata must be present in the plant community structure within the wetland, with the exception of sedge meadows or other wetland environments identified as exceptions to this standard.

Field survey data showing species observed, the category of strata (trees, shrubs, low shrub/liana, herbs or mosses) and the percent coverage of each within the dominant Cowardin habitat zones.

Related HGM Variables: *Vstrata*

Related HGM Functions: Plant Communities, Bird Habitat, Invertebrate Richness, General Habitat Function

Rational: The number of strata (trees, shrubs, low shrub/liana, herbs and mosses) in a plant community is important because different species use different strata for feeding and breeding. More mature plant communities generally have more strata present and, in that way, provide more habitat opportunities for animals. The majority of the 19 wetlands surveyed had at least three strata with, at minimum, 20% coverage, within the dominant plant community associations (emergent, scrub-shrub and forested zones).

Methods: Vegetation survey data from the PSWSMRP were reviewed to determine the number of strata and percent of coverage within each Cowardin habitat class. Species were classified according to strata and the presence and coverage of strata within all plots in a wetland was evaluated. If plants of a given strata covered greater than 32% of the plot area the strata was considered represented in the plot. If the strata was present in more than 20% of plots it was counted as present in the wetland.

Definition: Percentage of area covered by thin-stemmed emergents within the wetland.

Reference Standard: Varied from less than 10% of the wetland to 30 to 50% of the wetland.

Project Performance Standard: Wetlands created for amphibian habitat should have thin-stemmed emergent plants comprise at least 30% or more of the total wetland area.

Related HGM Variables: NA

Related HGM Functions: NA

Rational: Thin-stemmed emergents have been identified as important for supplying amphibian species with desired egg laying structures. The standard is based on evaluating the percent of wetland area dominated by thin-stemmed emergents in wetlands known to have highly diverse amphibian communities (shown in the shaded bars in Table 29) and comparing them with the area of thin-stemmed emergents in other wetlands.

Methods: Aerial photos were used to estimate the percentage of wetland area covered by emergent plants. Vegetation sampling data was then evaluated to determine the percent of thin-stemmed emergents within the emergent communities of each wetland. These data are shown in Table 29.

Table 29. Estimates of emergent area and percent coverage of thin-stemmed emergents.

Wetland	Percent of Wetland Plots in PEM and PAB Areas	Aerial Photo Estimate of Area	Percent Thin-Stemmed Emergents Within PEM and PAB Plant Communities	Final Estimated Category
AL3	0.00	<10%		<10%
B3I	0.12	<10%	2%	<10%
BBC24	0.63	50-80%	20%	10-30%
CL	0.08	No photo	28%	<10%
EC21	0.00	No photo		<10%
EC28	0.33	No photo	10%	10-30%
EC29	0.50	No photo	77%	30-50%
ELS34	0.03	No photo	28%	<10%
ELS39	0.13	<10%	0%	<10%
ELS61	0.33	10-30%	4%	10-30%
ELW1	0.00	<10%		<10%
FC1	0.20	10-30%	2%	<10%
HC13	0.22	10-30%	0%	<10%
JC28	0.06	<10%	27%	<10%
LCR93	0.00	<10%		<10%
LPS9	0.04	10-30%	1%	<10%
MGR36	0.60	30-50%	3%	<10%
NFIC12	0.00	<10%		<10%
PC12	0.37	30-50%	35%	30-50%
RR5	0.27	30-50%	21%	10-30%
SC4	0.00	<10%		<10%
SC84	0.03	<10%	0%	<10%
SR24	0.40	50-80%	84%	30-50%
TC13	0.22	10-30%	1%	<10%

Definition: Surface water source to the wetland.

Reference Standard: All study sites had surface water inputs.

Project Performance Standard: Use surface water as the wetland's principle water supply.

This standard can be demonstrated by satisfying the hydrology criteria for wetland delineation.

Related HGM Variables: NA

Related HGM Functions: NA

Rational: Wetland creation and restoration projects routinely fail due to poor hydrologic analysis, planning and design. Unlike near surface (interflow) and groundwater, surface water flows can be calibrated with field gaging and analyzed using hydrologic models. These model results can be used to size surface water conveyance systems so as to route sufficient storm water into wetland mitigation projects.

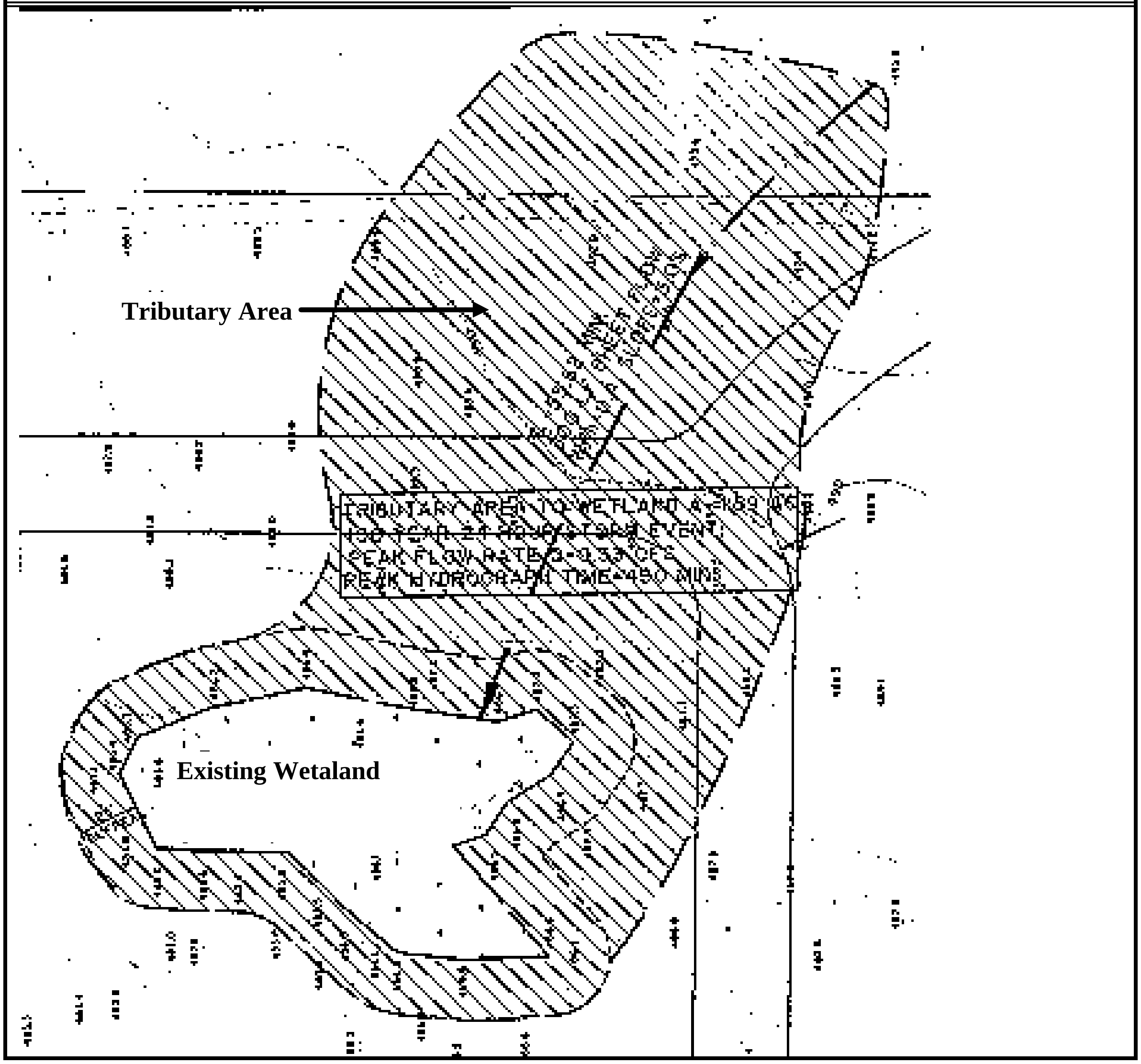
Methods: Wetland Hydrology Management Guidelines

The Puget Sound Wetlands & Stormwater Management Research Program has developed guidelines for managing wetland hydroperiods post-development. These guidelines have, however, proven to be difficult to translate into engineering requirements for development proposals. In order to resolve these problems the following technical guidelines have been developed.

These guidelines provide methods for determining pre-development wetland hydrology and designing surface water conveyance systems to maintain this hydrology post-development. Two methods have been developed, a simple method using the King County Runoff Time Series (KCRTS) hydrologic program, and a more accurate method using calibrated Hydrologic Simulation Program - Fortran (HSPF).

The 'Basic' analysis is applied to wetlands that have low to moderate functions. A 'High Value' analysis has been developed for wetlands that have high functions. Wetland functions may be determined by utilizing the 'Wetland and Buffer Functions: Semi-Quantitative Assessment Methodology' (Cooke 1995). This method establishes three 'groups' of wetland functions. Group 1 are roughly 'low' functioning wetlands while Groups 2 and 3 are 'moderate' and 'high' functioning wetlands.

Figure 12. Wetland Catchment

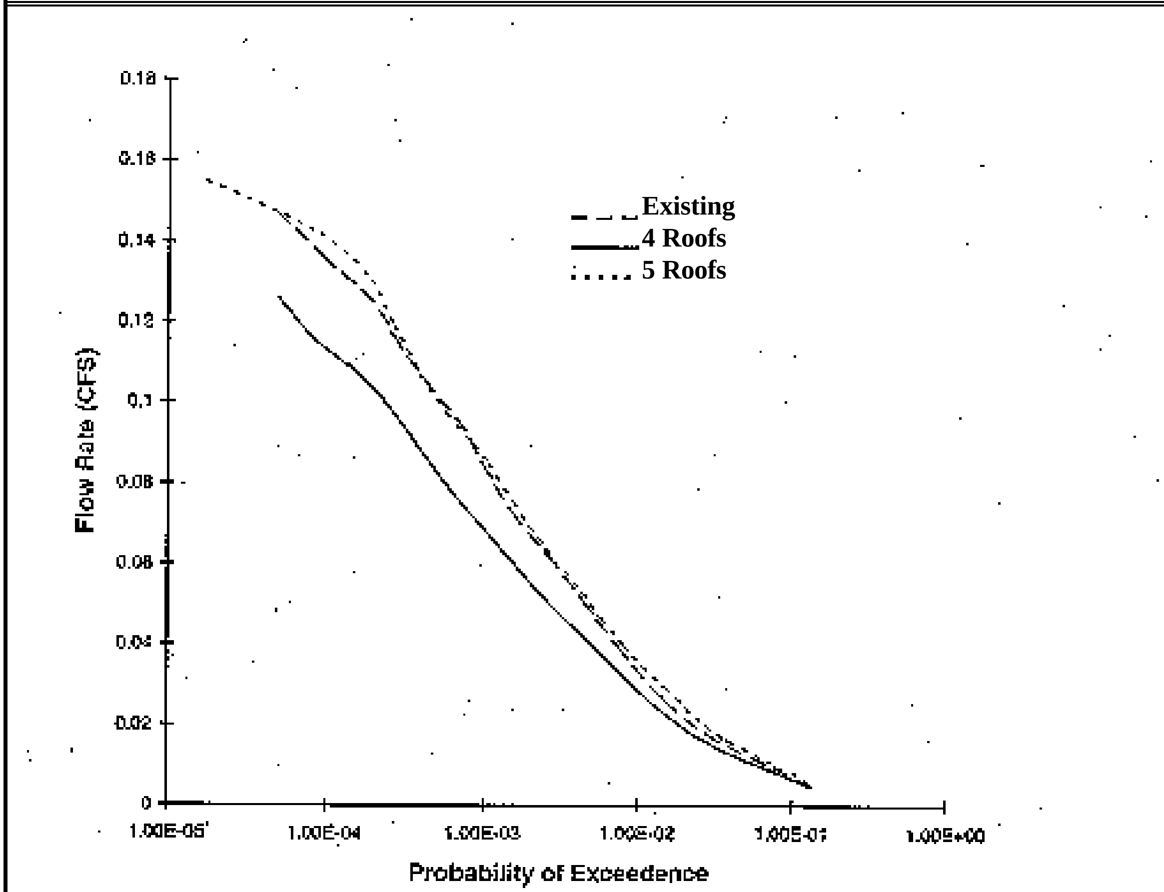


Basic Analysis (HSPF w/ Regionalized Parameters, or KCRTS)
This analysis does not model the wetland hydraulics, but instead matches the project's hydrologic contribution to the wetland. The basic analysis is performed with the full historical runoff files as statistics will be performed on partial water years, which the reduced 8-year runoff files were not designed for. The basic analysis should be combined with BMP's (e.g. dispersion, infiltration, energy dissipation, etc.) designed to closely match the transport characteristics of the existing site's hydrologic contributions to the wetlands. (i.e. does flows from the existing site enter the wetland via concentrated surface flow, as interflow, or combination of both?).

- determine the wetland contributing basin area (Figure 12. Wetland Catchment), and soil and landcover types.
- determine the pre-development probability of flow exceedence (flow durations) for different periods of the water year, as described below in Time Period of Interest.

- determine the post-development probability of flow exceedence (flow durations) for the same time periods used in b. Different site development scenarios should be analyzed to determine the optimum developed site configuration.
- determine the optimum developed site conditions which best match the pre-development frequency of exceedence (Figure 13. Routing Surface Water to a Wetland).
- modifying the post-development contributing basin area (bypass increased volumes around wetland).
- increased forest retention.
- infiltrate/disperse increased runoff volumes.

Figure 13. Routing Surface Water to a Wetland



Flow Rate Duration Curves: Curves are shown for existing conditions and developed conditions with four and five roofs discharging to the wetland. Routing five roofs to the wetland more closely matches existing conditions.

Time Period of Interest -

Group 1 wetlands, perform analysis seasonally with Spring and Summer being of primary concern to maintaining wetland functions. Spring is defined as February 1, through May 31, Summer is June 1, through August 31, Fall is September 1, through November 30, and Winter

is December 1, through January 31. Seasons may be adjusted based on specific wetland characteristics (e.g. bogs may have a different critical season than lakes).

Group 2 wetlands not required to perform High Value Analysis: (Time period shorter than seasonal during critical season(s)). Perform partial-year duration analysis for each month during the wetlands critical season(s), use seasonal timestep for remainder of year. The shorter time period will better match the existing, time variable, hydrologic contributions from the site. The time period could be reduced further to a minimum of 1 week, which would essentially analyze flow durations on a storm by storm basis. An initial goal of matching the majority of partial-year flow durations should be used. Final determination as to the optimum site configuration will be agreed to through the engineering plan review process, in conjunction with review by county and/or private wetlands biologists.

The increased number of data points resulting from a shorter time period will likely require more judgment as to the optimum developed site configuration, as it is likely that different storm types will produce variable changes in runoff response under different land use assumptions (e.g. a thunderstorm may produce little to no runoff under existing conditions. A fixed structure set to bypass the increased runoff from that storm may divert too much volume during a long duration winter storm). In other words, it is likely that a project will not be able to match, to the same level, the partial-year flow durations for all time periods, and therefore judgment must be applied.

Proposals to modify the wetland hydraulics (storage or discharge) to control impacts should perform a calibrated HSPF analysis to measure fluctuations, as described in 2. below.

High Value Analysis (Calibrated HSPF) Group 3 wetlands.
Use combination of existing MDP procedures and PSWSMRP guidelines to analyze wetland water level fluctuations. Determine the water level fluctuation (WLF) for the wetland by gaging the wetland for 1 year. Use a combination of groundwater wells and crest-stage gages or continuous recording gages. Survey the topography of the wetland at a minimum of 1 foot contours. Perform a stage excursion analysis for 72 hour intervals. Limit stage excursions post-development using the PSWSMRP guidelines.

Note: Comparisons of existing and proposed conditions should be done based on calibrated simulations. Many of the errors in the analysis (e.g. reservoir hydraulics) will cancel (to a large extent) if both conditions are simulated.

Definition: The amount, size, and distribution of woody debris in the wetland.

Reference Standard:

	40 to 214 m^3.
Small	11 to 40%
Medium	26 to 31%
Large	30 to 60%
	7:1 to 17:1 coniferous to deciduous wood
	49 to 193 snags per hectare

Project Performance Standard: Field surveys should demonstrate that the average volume of woody debris equals or exceeds 135 m^3 per hectare. Of this woody debris, a minimum of 30% of the volume (63 m^3) should have a Decay/Size rating of Large, that is, composed of logs at least 21 cm in diameter and greater than 6 meters in length from within any decay class. The survey should show that the ratio of coniferous to deciduous woody debris is a minimum of 7:1 and that the average number of snags equals or exceeds 115 per hectare.

Related HGM Variables: *Vtfwoody,*

Related HGM Functions: Amphibian Habitat, Invertebrate Richness, General Habitat Functions

Rational: Coarse woody debris in wetlands is important for providing nesting materials, habitat for invertebrates, food for predators and moisture during the dry season. Performance standards for coarse woody debris and snags were developed from data obtained in a special study of four wetlands. This study indicated that the distribution of coarse woody debris, snags and greentops was found to be random and highly variable in the landscape. In general, there were very few greentops but many snags and decaying logs (coarse woody debris). The largest number of greentops found in a wetland was 17 and the lowest, one. We found greentops to be insignificant when compared to the number of snags and the amount of coarse woody debris so no performance standards were developed addressing greentop distribution. The sizes of the snags, greentops and wood that was observed within each transect sample area are shown in Table 36. Volumes were calculated for coarse woody debris, and the recommended standards are based on the average volume found among all wetlands. Performance standards for snags were based on counts and not volumes.

Methods: Coarse Woody Debris Volume, Size Distribution and Species.

Coarse wood debris volumes ranged from 40 to 214 m^3 per hectare within a single wetland with an average among all the wetlands surveyed of 135 m^3 per hectare (Table 30). TC13 was substantially lower than the other wetlands, however all wetlands exhibited a broad range of debris volumes.

Table 30: Coarse woody debris volumes by wetland

Wetland	Total Sample Area (m^2)	Total Volume of Woody Debris (m^3)	Volume of Woody Debris per Hectare (m^3)
AL3	21052.76	332.35	157.87
BBC24	22553.75	283.43	125.67
SR24	15649.60	335.50	214.38
TC13	20792.86	83.95	40.37
		Average for All Wetlands	134.57

The size distribution of the woody debris are shown in Table 31. Distribution of debris sizes between wetlands was consistent with the exception of TC13, in which we found a much larger percentage of small woody debris, 40 percent versus a range of 11 to 16 percent among the other wetlands. The average for small debris was 20 percent over all the wetlands. Medium sized logs consistently ranged close to 30 percent among all wetlands. Large logs ranged between 55 and 60 percent for all wetlands with the exception of TC13, which was 30 percent. The averages of 20, 30 and 50 percent were used as the minimum performance standard for small. medium and large woody debris, respectively. Larger debris is generally considered superior to smaller debris for habitat functions, therefore the performance standard allows for the use of more than 50 percent large sized woody debris as a substitute for the small and medium classes.

Table 32: Portion of woody debris by size per hectare.

Wetland	small: 15-0.2 m and < 6m, or ≤ 50cm and ≤ 3m	medium: > 0.5 m and ≤ 3 m, or 20-50cm and 3-6 m, or 15-20cm and > 6m	large: 20-50cm and >6 m or, >50cm and > 3m
AL3	0.11	0.29	0.60
BBC24	0.16	0.26	0.57
SR24	0.14	0.31	0.55
TC13	0.40	0.30	0.30
Average for All Wetlands	0.20	0.29	0.50

The approximate number of logs of each diameter and length class required to reach the proportion of volumes specified by the standard is shown in Table 33. The chart shows the percentage of wood that is recommended for that class followed by the number of logs of that size needed to meet the volume requirement. To reiterate, larger woody debris may be used as a substitute for smaller woody debris but smaller woody debris may not be substituted for larger debris size requirements.

Table 33: Percentage of volume and number of wood logs needed per size class to achieve 135 m^3.

	Diameter		
Length	15-20cm	21-50 cm	>50cm
0-3 m	20% 675	20% 180	30% 60
3.1-6 m	20% 245	30% 89	50% 34
>6 m	30% 134	50% 76	50% 17

The ratio of deciduous to coniferous woody debris was measured and evaluated over all the wetlands. The data, shown in Table 34, shows that coniferous outnumbers deciduous woody debris by at least seven times and is as high as nineteen times in one wetland. The average ratio among all wetlands was 13 to one dominated by coniferous wood. The performance standard recommends that, at minimum, coniferous wood should dominate deciduous wood seven to one by volume, the lowest observed among the wetlands sampled.

Table 34: Ratio of deciduous to coniferous woody debris

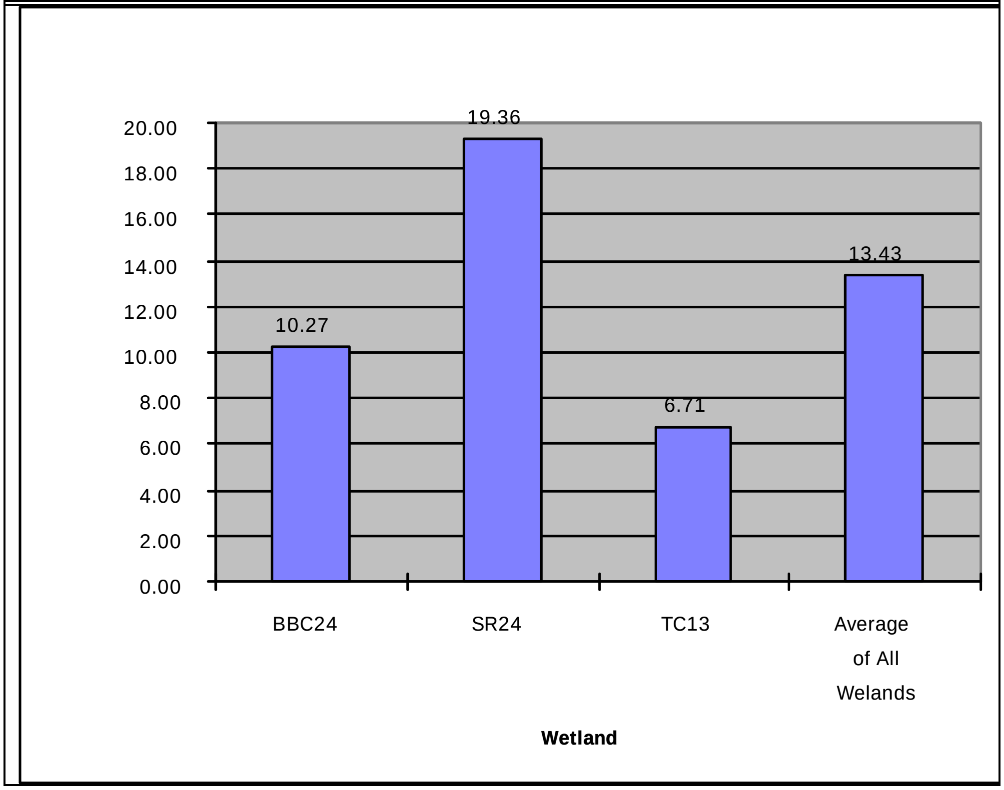


Table 35 shows the percentages of woody debris found for each species. The table shows that Western red cedar (*Thuja plicata*) dominates in all of the wetlands. It is recommended that the greatest proportion of coarse woody debris be Western red cedar, when possible, to obtain the highest wetland functions provided by coarse woody debris..

Table 35: Distribution of coarse woody debris by species

Wetland	Douglas Fir	Grand Fir	Quaking Aspen	Red Alder	Red Cedar	unknown	Western Hemlock	Willow
AL3	4.17%	0.00%	0.00%	4.10%	48.54%	24.69%	18.50%	0.00%
BBC24	15.14%	0.00%	0.48%	8.16%	64.63%	2.68%	8.92%	0.00%
SR24	27.20%	0.21%	0.00%	3.97%	41.91%	11.47%	14.87%	0.38%
TC13	20.50%	0.00%	0.00%	10.71%	32.94%	17.39%	18.46%	0.00%
Average of all wetlands	0.17%	0.00%	0.00%	0.07%	0.47%	0.14%	0.15%	0.00%

Methods: Snags

Snags were counted along each transect area and tabulated. The total number of snags in each wetland was calculated in relationship to the total area surveyed. Table 36 shows the total number of snags and the total area surveyed for each wetland. These results were used to ratio the number of snags found in one hectare.

Table 36: Snags found in wetlands.

Wetland	greentop	snag	Total Greentops and snags	Sample Area (m^2)	Number of Snags per Hectare
AL3	31	256	287	21065.1	122
BBC24	3	199	202	20409.7	98
SR24	14	307	321	15979.2	192
TC13	7	103	110	21205.7	49

The wetlands studied all have emergent, scrub-shrub and forested zones but, it should be noted, these zones were not of equal size or proportion. Snags ranged from 49 to 192 per hectare, exhibiting quite a large difference among the wetlands studied. The average among all the wetlands was 115 snags per hectare. The number of snags found in TC13 (49), a primarily deciduous , young, forested wetland was substantially lower than the next highest wetland, BBC24, which is predominantly an emergent wetland, and where the number of snags was 98 per hectare. AL3 is dominated by scrub-shrub communities and was the second highest at 122 snags per hectare. SR24, which has a full range of habitat classes, but is primarily scrub-shrub and emergent was highest with 192 snags per wetland.

The average of 115 snags per hectare, was selected as the wetland performance standard. It is expected that the number of snags would increase over time through natural wetland successional and disturbance processes.

Methods: Each snag, greentop and piece of coarse woody debris greater than 0.15m was categorized according to diameter, length, state of decay and species. The length and width classes, shown in Table 1, were used to calculate theoretical volumes of the debris based on the following assumptions:

- Volumes were calculated using the geometric calculation for the volume of a cylinder:

$$(\pi*1/2\ \text{Diameter}^2) * \text{Length} = \text{Wood Volume } (m^3).$$

- Actual diameters and lengths were based on the midpoint (rounded up) between the low and high of the category range.
- Since no high range was given for the two highest categories for diameter and length (>0.5 m and > 6 m) these values were based on 150% of the low value

given or 0.75 m and 9 m, respectively.

Table 38 shows the volume of woody debris attributed to each category of diameter and length classification. Woody debris within these classes were then ranked according to volume as shown in Table 39. These rankings were used as a basis for the size classifications of large medium and small.

The calculated volumes of woody debris, provided by Table 38, were totaled for pieces of woody debris observed in the transect sample area for each wetland. The total volume for the wetland area was used as a basis for calculating the proportion found in one hectare, providing a basis for comparing the wetlands and determining the standard.

Table 37 shows a ranking of the logs found based on the diameter and length classification and also including decay class. Decay class two or medium decay was considered the best, followed by three, soft wood, and one, no or minimal decay. Decay class was tabulated but no standards for decay class were developed.

Table 38. Table of coarse woody debris volumes (m^3).

	Diameter Class/Diameter Calculated		
Length Class/Length Calculated	0.15-0.2 m/0.18 m	0.21-0.5 m/0.36 m	>0.5 m/0.75 m
0-3 m/1.5 m	0.04	.15	.67
3.1-6 m/4.5 m	.11	.45	2.0
>6 m/9 m	.23	.9	4.0

Table 39. Diameter Length Ranking (based on volume).

	Diameter Class		
Length Class	0.15-0.2 m	0.21-0.5 m	> 50cm
0-3 m	1	3	6
3.1-6 m	2	5	8
>6 m	4	7	9

Table 40. Diameter, Length and Decay Classification				
	Decay Class			
Diameter Length Ranking	2 - medium Most Valuable	3 - soft	1 - hard	Debris Size Rating
Most Valuable 9	27	26	25	Large
8	24	23	22	Large
7	21	20	19	Large
6	18	17	16	Medium
5	15	14	13	Medium
4	12	11	10	Medium
3	9	8	7	Small
2	6	5	4	Small
1	3	2	1	Small

Change: The alteration in the structure and function of the ecological mosaic over time (Forman 1986).

Function: Functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of wetland ecosystems. Functions are made up suites of environmental variables (Brinson 1993).

Function Assessment: The process by which the capacity of a wetland to perform a function is measured. This approach measures capacity using an assessment model to determine a functional capacity index (Smith 1995).

Hydroperiod: The seasonal occurrence of flooding and/or soil saturation; encompasses the depth, frequency, duration, and seasonal pattern of inundation (Azous et al 1997).

Indicators: Indicators are easily observable characteristics that are correlated with a quantitative or qualitative "measure" of an environmental variable (Hruby et al 1997). Indicators are [ecological] variables so closely associated with particular wetland functions that their presence or value is symptomatic of the existence or level of function (Kentula 1992).

Infiltration: Movement of water through the soil surface into the ground (McGraw-Hill 1984).

Perched Water: Groundwater that is unconfined and separated from an underlying main body of groundwater by an unsaturated zone(McGraw Hill 1984).

Permeable Surface: A surface that permits movement of a fluid through it. The degree of permeability depends on the size and shapes of the pores in the surface, and on the extent, size, and shape of the connections between them. An impermeable surface does not permit the movement of a fluid through it (Allaby, 1989).

Project Performance Standards: Project performance standards are measurable benchmarks used to evaluate the development of ecological characteristics at some point in time. They are used as a standard of comparison against which the mitigation project can be compared.

Project Target. The level of functioning identified or negotiated for a restoration or creation project. Must be based on reference standards and/or site potential and be consistent with restoration or creation goals. Used to evaluate whether a project is developing toward reference standards and/or site potential (Smith 1995).

Reference Domain: The geographic area from which reference wetlands are selected (Smith 1995). All wetlands within a defined geographic region that belong to a single

hydrogeomorphic subclass (Brinson 1995).

Reference Standards: Conditions exhibited by a group of reference wetlands that correspond to the highest level of functional capacity (highest, sustainable level of functioning) across the suite of functions performed by the regional wetland subclass (Smith 1995).

Reference Standard Sites: The sites within a reference wetland data set from which reference standards are developed. Among all reference wetlands, these are judged by an interdisciplinary team to have the highest levels of functioning (Brinson 1995).

Reference Wetlands: Wetland sites that represent the range of variability exhibited in a regional wetland subclass as a result of natural processes and anthropogenic disturbance (Smith 1995). The sites within a reference wetland data set from which reference standards are developed (Brinson 1995). Reference wetlands are used to develop reference standards (Smith 1995).

Regions: Geographic areas that are relatively homogenous with respect to climate, geology, and other large scale factors that influence how wetlands function (Smith 1995).

Site Potential: The highest level of functioning possible given local constraints of disturbance history, land use, and other factors. Site potential may be equal to or less than levels of functioning established by reference standards (Lee 1995).

Structure: The spatial relationships among the distinctive ecosystems or "elements" present - more specifically, the distribution of energy, materials, and species in relation to the size, shapes, numbers, kinds, and configurations of the ecosystems (Forman 1986).

Variable: Variables represent the environmental characteristics that are considered to be important in the performance of a function (Hruby et al 1997).

7. References

Adamus, P.R. E.J. Clarain, Jr., R.D. Smith and R.E. Young. 1987. Wetland Evaluation Technique (WET) Volume II: Methodology. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS. Operational Draft Technical Report Y-87-Department of the Army and Federal Highway Administration (FHWA-IP-88-029).

Azous, A. L., L. E. Reinelt and J. Burkey. 1997. Managing Wetland ydroperiod: Issues and Concerns. Chapter 13 p. 187-197 In Azous, A. L. and R. R. Horner (eds.). In Wetlands and Urbanization: Final Report of the Puget Sound Wetlands and Stormwater Management Research Program. Washington State Department of Ecology, Olympia, Washington & University of Washington, Seattle, Washington, USA.

Azous, A. L. and R. R. Horner (eds.). 1997. Wetlands and Urbanization. Final Report of the Puget Sound Wetlands and Stormwater Management Research Program. Washington State Department of Ecology, Olympia, Washington & University of Washington, Seattle, Washington, USA.

Castelle, A. J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, M. Bentley, D. Sheldon and D. Dole. 1992. Wetland Mitigation Replacement Ratios: Defining Equivalency. Adolfson Associates, Inc., for Shorelands and Coastal Zone management Program, Washington State Department of Ecology, Olympia, Publ. No. 92-08.

future.. Puget Sound Wetlands & Stormwater Management Research Program

Hruby, T. C. Brower. 1994. Guidelines for Developing Freshwater Wetlands Mitigation Plans and Proposals. Washington State Department of Ecology. Publication #94-29. Olympia, WA.

Hruby, T. and W.E. Cesanek and K.E. Miller. 1995. Estimating Relative Wetland Values for Regional Planning. Ecology. 15:93-107.

Hruby, T., K. Brunner, S. Cooke, K. Dublanika, R. Gersib, T. Granger, L. Reinelt, K. Richter, D. Sheldon, A. Wald, F. Weinmann. 1997. Draft Models to Assess Riverine and Depressional Wetlands in Western Washington. Washington State Department of Ecology. Olympia, WA. USA.

Kentula, M.E., R.P. Brooks, S.E. Gwin, C. C. Holland, A.D. Sherman, and J.C. Sifneos. 1992. In Wetlands: An Approach to Improving Decision Making in Wetland Restoration and Creation. Island Press, Washington DC, USA.

King County Zoning Code Title 21A. 1993. King County Department of Development and Environmental Services. Renton, WA. USA

King County Mitigation Banking Policies. 1997. King County Department of Natural Resources. Seattle, WA.

King County 1997a. Surface Water Design Manual.

King County 1997b. Runoff Time Series Analysis.

Kusler, J.A. and Kentula, M.E. (eds.). 1990. Wetland Creation and Restoration: The Status of the Science. Island Press, Washington, DC.

Lee, L.C. & Associates. 1995. University of Washington-Bothell Cascadia Community College Collated Campus: 75% Design for Restoring the North Creek Channel and Floodplain Ecosystem. L.C. Lee & Associates. Seattle, WA, USA

Marble, A.D. 1992. A Guide to Wetland Functional Design. Lewis Publishers. Chelsea, MI.

Ossinger, Mary. 1997. Objectives and Standards of Succes for Wetland Mitigation Projects - a Guidelines. Washington State Department of Transportation. Olympia, WA.

Redmond, A. 1992. How Effective is Mitigation. National Wetlands Newsletter. 14:5-6.

Reed, P. R. 1988. Jr. National List of Plant Species that Occur in Wetlands: Northwest (Region 9). U. S. Fish and Wildl. Serv. Biol. Rep. 88(26.9). 88pp.

Reed, P. R., D.Peters, J. Goudzwaard, I. Lines, F. Weinmann. 1993. 1993 Supplement to the

List of Plant Species that Occur in Wetlands: Northwest (Region 9). U. S. Fish and Wildl. Serv. Biol. Rep. 88(26.9). 88pp.

Reinelt, L.E. and Horner, R.R. 1990. Characterization of the Hydrology and Water Quality of Palustrine Wetlands Affected by Urban Stormwater. King County Resource Planning, King County, WA, USA

Reinhardt, R.D., M.M. Brinson, P.M. Farley. 1997. Applying wetland reference data to functional assessment, mitigation, and restoration. Wetlands 17:195-215.

Reppert, R. T., Sigleo, W., Stackhiv, E., Massman, L., Meyers, C., 1979. Wetland Values: Concepts and Methods of Wetland Evaluation. IWR Res. rep. 79-R-1, U.S. Army Corps of Engineers, Fort Belvoir, VA.

Richter, K. O. and A. L. Azous. 1993. Amphibian occurrence and wetland characteristics in the Puget Sound Basin. Wetlands 15:305-312. Society of Wetland Scientists.

Richter, K.O. 1995. Criteria for the Restoration and Creation of Wetland Habitats of Lentic-Breeding Amphibians of the Pacific Northwest. Unpublished Manuscript.

Richter, K.O., R.R. Horner, and S.S. Cooke, 1997. Monitoring to Establish Reference Conditions for Freshwater Wetlands Restoration. Edited by K. Ewing, and S.M. Allen. U.S. Environmental Protection Agency, Western Division, National Health and Environmental Laboratory, Corvallis, OR.

Richter, K.O. and A.L. Azous. 1997a . Amphibian distribution, abundance and habitat use. Chapter 5. p. 84-97 In Azous, A. L. and R. R. Horner (eds.) Wetlands and Urbanization. Final Report of the Puget Sound Wetlands and Stormwater Management Research Program. Washington State Department of Ecology, Olympia, Washington & University of Washington, Seattle, Washington, USA

Richter, K.O. and A.L. Azous. 1997b.. Bird Communities In Relation To Watershed Development. Chapter 6. p. 98-114 In Azous, A. L. and R. R. Horner (eds.) Wetlands and Urbanization. Final Report of the Puget Sound Wetlands and Stormwater Management Research Program. Washington State Department of Ecology, Olympia, Washington & University of Washington, Seattle, Washington, USA

Richter, K. O. and A. L. Azous. 1997c. Small Mammal Distribution, Abundance And Habitat Use. Chapter 7 p. 115-124. In Azous, A. L. and R. R. Horner (eds.) Wetlands and Urbanization. Final Report of the Puget Sound Wetlands and Stormwater Management Research Program. Washington State Department of Ecology, Olympia, Washington & University of Washington, Seattle, Washington, USA

Richter, K.O. and A.L. Azous. 1997d . Bird communities in relation to watershed development. Chapter 12. p. 178-186. In Azous, A. L. and R. R. Horner (eds.) Wetlands and Urbanization. Final Report of the Puget Sound Wetlands and Stormwater Management

Research Program. Washington State Department of Ecology, Olympia, Washington & University of Washington, Seattle, Washington, USA

Roth, E.M., R.D. Olsen, P.L. Snow, and R.R. Sumner. 1993. Oregon Freshwater Wetland Assessment Methodology. Ed. by S.G. McCannell. Oregon Division of State Lands. Salem, OR.

Smith, R.D., A. Amman, C. Bartoldus, and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. U.S. Army Engineers Waterways Experiment Station Technical Report TR WRP-DE-10, and Operational Draft, Vicksburg, MS. USA.

Taylor, B. L. 1993. The Influence of Wetland and Watershed Morphological Characteristics on Wetland Hydrology and Relationships to Wetland Vegetation Communities. M. S. C. E. Thesis, Department of Civil Engineering, University of Washington, Seattle, WA, USA.

Washington Department of Ecology. 1993. Washington State Wetland Rating System - Western Washington. Publication #93-74. Washington Department of Ecology. Olympia, WA, USA.

Wilson, R.F and Mitsch, W.J. 1996. Functional assessment of five wetlands constructed to mitigate wetland loss in Ohio, USA. Wetlands. 16:436-251.