Chapter 6

The Science and Effectiveness of Wetland Mitigation

6.1 Reader's Guide to this Chapter

This chapter synthesizes the scientific literature regarding compensatory mitigation and its effectiveness at reducing the severity of activities that detrimentally affect wetlands. It also reports the suggestions made by various authors regarding ways to improve compensatory mitigation.

6.1.1 Chapter Contents

Major sections of this chapter and the topics they cover include:

Section 6.2, Introduction and Background to Wetland Mitigation describes wetland mitigation sequencing, which encompasses a series of actions that requires addressing each action, or step, in a particular order. Compensation for wetland impacts is just one of these steps.

Section 6.3, Success of Compensatory Mitigation Wetlands synthesizes the literature on the biological, ecological, or functional success of compensatory mitigation projects. This section does not specifically evaluate the successful compensation for wetland area; that is discussed in Section 6.7.

Section 6.4, Compliance with Permit Requirements describes studies that evaluated several aspects of how well compensatory mitigation projects met legal or permit requirements. These included whether projects were completed or installed according to plan, whether they attained the required wetland acreage, whether performance standards were achieved, whether the project was monitored or maintained, and whether the regulatory agencies followed-up on the project.

Section 6.5, Types of Compensatory Mitigation discusses the use and effectiveness of restoration, creation, enhancement/exchange, preservation, mixed compensatory mitigation, mitigation banking, and in-lieu fees.

Section 6.6, Replacement Ratios describes the rationale for the use of ratios in determining the acreage required as compensation for a given area of wetland impact. It synthesizes the literature on the ratios that were required and those actually achieved for numerous projects. This section also discusses approaches proposed in the literature to more effectively determine compensatory mitigation ratios.

Section 6.7, Replacement of Wetland Acreage summarizes the results of studies examining whether compensatory wetland mitigation is actually replacing the acreage of wetland losses authorized. This includes both evaluations of overall permitting programs and of specific compensation projects in compensating for wetland acreage.

Section 6.8, Functions and Characteristics Provided by Created, Restored, or Enhanced Wetlands describes the ability of mitigation wetlands to provide wildlife habitat, plant communities, adequate soil conditions, and water quality/quantity functions. Compensation wetlands were often compared with pre-existing or reference wetlands in these studies.

Section 6.9, Reproducibility of Particular Wetland Types summarizes the literature regarding whether and how easily certain wetland types, such as bogs, fens, vernal pools, alkali wetlands, and mature forested wetlands, can be reproduced or restored.

Section 6.10, Suggestions from the Literature for Improving Compensatory Mitigation summarizes numerous recommendations made by researchers to improve the success of compensation projects—ranging from improvements to regulations and site selection, to better performance standards, to a broader landscape approach, to mitigation banking.

Section 6.11, Chapter Summary and Conclusions ties together the major concepts presented in the chapter.

6.1.2 Where to Find Summary Information and Conclusions

Each major section of this chapter concludes with a brief summary of the key points resulting from the literature review on that topic in a bullet list format. The reader is encouraged to remember that a review of the entire section preceding the summary is necessary for an in-depth understanding of the topic.

For summaries of the information presented in this chapter, see the following sections:

- Section 6.3.2
- Section 6.4.9
- Section 6.5.8
- Section 6.6.4
- Section 6.7.3
- Section 6.8.6
- Section 6.9.5
- Section 6.10.7

In addition, Section 6.11 provides a summary of the chapter and conclusions about the overarching themes gleaned from the literature and presented in this chapter.

6.1.3 Sources and Gaps in Information

The synthesis in this chapter is based on more than 50 articles, government reports, and conference proceedings that have been published since about 1990 on the topic of compensatory mitigation. (The literature did not address the other types of mitigation listed in Section 6.2.1.)

The information resulted from studies conducted in various states and countries, including several studies from the Pacific Northwest. Environmental conditions may vary in other states and countries. However, the information resulting from these studies is relevant to compensatory wetland mitigation in Washington State for the following reasons:

- The general principals and techniques used to restore, create, and enhance wetlands are similar
- The regulatory approaches and requirements are similar
- Most importantly, the studies provide similar and consistent results

Geographic location of the studies cited in this chapter

The articles and reports that evaluated the effectiveness of individual compensatory mitigation projects focused on a variety of locations, including Washington, Oregon, California, Louisiana, Michigan, Indiana, Ohio, New Jersey, Massachusetts, Maryland, Tennessee, and Florida.

Studies that assessed specific functions performed by wetlands that were sites for compensatory mitigation and non-regulatory restoration were located in: Washington, Oregon, Wyoming, Iowa, Minnesota, Wisconsin, Illinois, Ohio, New York, Pennsylvania, Connecticut, West Virginia, South Carolina, Florida, Canada, Sweden, Spain, Austria, and central Europe.

The information synthesized in this chapter covers a range of topics and issues relating to compensatory wetland mitigation (refer to Chapter Contents, Section 6.1.1). Yet there are some topics and issues for which no scientific information was found. For example, studies were found that examined whether compensation projects had performance standards and whether the performance standards were met. However, no studies were found that explored why performance standards were not met. Other examples of data gaps include studies that:

- Determined the effectiveness of local critical area ordinances at replacing permitted wetland losses
- Examined the effect of construction inspections, monitoring, maintenance, or performance bonding on the success or level of compliance of projects
- Compared the level of success of newly installed versus more established compensation sites

- Looked specifically at the quality and effectiveness of preservation sites
- Focused specifically on wildlife habitat provided by restored, created, or enhanced wetlands in urban settings
- Examined the effects of mitigation decisions on a watershed scale
- Looked at the reproducibility of alkali wetlands

The articles and reports reviewed used a variety of terms to define what they were assessing or evaluating. For the purposes of this synthesis, *effectiveness* is used as a general term referring to how compensatory wetland mitigation was doing overall, including evaluations of success, compliance, and functions and characteristics. These terms will be defined more precisely in subsequent sections.

6.2 Introduction and Background to Wetland Mitigation

6.2.1 Wetland Mitigation Sequence

Mitigation is a series of actions that requires addressing each action, or step, in a particular order. This sequence of steps is used to reduce the severity of negative impacts from activities that potentially affect wetlands. When a change in land use has the potential to adversely affect a wetland, regulatory agencies require the applicant to illustrate how the project has considered the six sequential steps of mitigation. According to the rules implementing the Washington State Environmental Policy Act (Chapter 197.11 WAC), mitigation involves the following:

1. *Avoiding the impact altogether by not taking a certain action or parts of an action;*

2. *Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;*

3. *Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;*

4. *Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;*

5. *Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or*

6. *Monitoring the impact and taking appropriate corrective measures* (WAC 197.11.768).

The authors of Volume 1 provide a brief explanation and examples of the steps in the mitigation sequence in the following paragraphs.

Avoidance is the first step in the mitigation sequence. Avoidance of impacts means that there is no direct loss of wetland area and functions. Avoidance does not, however, eliminate indirect losses of wetland function. For example, consider a hypothetical proposal to develop a 5-acre parcel of land. The parcel contains 2 acres of wetland. The development is designed around the wetland and will therefore avoid any direct loss. Avoidance has occurred. Yet if buildings and parking lots surround the wetland, indirect impacts to wildlife habitat and hydrology may occur in the form of fragmentation and altered hydroperiod.

Minimization of adverse impacts is the second step. It can reduce the extent of wetland impacts when a project is redesigned to lessen wetland alteration. However, it does not eliminate the direct or indirect loss of area and/or functions.

Rectification, the third step, assumes that losses in wetland area and/or function at the impact site are temporary and can be restored. For example, projects such as installing or maintaining an underground pipeline that passes through a wetland typically use rectification as a mitigation measure. In the example of the underground pipeline, vegetation, soil, and water movement may be disturbed and altered. The wetland area and/or functions are temporarily changed or lost. Rectification would entail replacing the soil, restoring the water movement, and restoring the vegetation.

The fourth step of the mitigation sequence is not generally relevant to wetlands, and therefore, no examples of its application are provided.

Compensation for unavoidable adverse impacts, the fifth step, involves restoring, creating, enhancing, or preserving wetland area to replace or make-up for the wetland area and functions that were lost or altered. It is discussed in much greater detail in the following sections.

Monitoring, step 6, is used to address the potential impact to wetlands that may result from a project when specific impacts are not known. If impacts are observed during or after project completion, actions should be taken to address the loss of wetland functions. For example, if a bridge is built over a river fringed by wetlands, the bridge may shade portions of the wetlands. Though no wetlands would be filled during construction, the shading could alter the performance of functions, thereby resulting in impacts to wetlands. To address the potential risk of impacts to wetlands, the project could be monitored to determine the effect of shading on the riverine wetlands. If monitoring reveals that the functions of the riverine wetlands were adversely altered, then compensation might be required.

The scientific literature reviewed for this synthesis did not contain information on the use or effectiveness of any of the mitigation measures defined above, except compensatory mitigation, which is the focus of the remainder of this chapter.

6.2.2 The Emergence of Compensatory Wetland Mitigation

The term *compensatory mitigation* refers to the compensation stage of the mitigation sequence (number 5 in the list of steps described earlier). Compensatory wetland mitigation generally entails performing one or more of the following types of compensation:

- Restoring wetland conditions (and functions) to an area
- Creating new wetland area and functions
- Enhancing functions at an existing wetland
- Preserving an existing high-quality wetland to protect it from future development

> The term **compensatory mitigation** refers to the compensation stage of the mitigation sequence (number 5 in the list of steps on the previous page). Because the regulatory requirements and policies tend to focus on the compensation stage, the term "mitigation" is often used to refer to compensation, which is just one part of the overall mitigation sequence.

The use of compensatory mitigation for wetland loss emerged in the 1980s (Roberts 1993, National Research Council 2001). The U.S. Army Corps of Engineers considered the process of mitigation as part of the National Environmental Policy Act of 1969. However, it wasn't until 1980 when the U.S. Environmental Protection Agency (EPA) issued new guidelines for Section 404(b)(1) of the Clean Water Act that mitigating for wetland losses by creating or restoring another wetland as compensation became widely acceptable (National Research Council 2001). Compensatory mitigation was seen as a way to speed up an arduous process of documenting avoidance and minimization efforts, while satisfying concerns about the loss of ecosystems and functions (Roberts 1993). Creating or restoring wetland area to compensate for permitted wetland losses was viewed and publicized as a way to allow development while preventing a net loss of wetland areas.

By the late 1980s, studies of the effectiveness of compensatory mitigation were emerging, with mixed results. The primary indication was that replacing or replicating an existing wetland was difficult, if not impossible (Kusler and Kentula 1990, National Research Council 2001). However, some wetland types and functions could be approximated given the proper conditions (Kusler and Kentula 1990, National Research Council 2001). This chapter focuses on studies published since 1990 that examined the effectiveness of compensatory mitigation.

6.3 Success of Compensatory Mitigation Wetlands

Compensatory mitigation "success" is poorly defined and often contentious (Kentula 2000). The literature refers to legal success, biological success, ecosystem success (Wilson and Mitsch 1996), functional success (Mockler et al. 1998), or some combination of these.

Compliance generally means the same as “legal success.” It is evaluated by comparing the actual on-the-ground, or as-built, conditions against what was required in the permit. Studies describing legal success are referred to as compliance in this document, and they are discussed in Section 6.4.

This section will focus on “biological, ecological, or functional success.” Therefore, when the term *success* is used in this chapter, it refers exclusively to biological, ecological, or functional success. Success involves an evaluation of the factors that characterize a wetland (e.g., hydroperiod, vegetation, soils), the performance of functions, or both. Best professional judgment and/or one of a variety of function assessment methods have been used by researchers to evaluate success.

The authors of Volume 1 have observed two main problems with evaluating the success of compensatory mitigation projects. First, success is often confused with compliance, and it is assumed that they must go hand in hand. In some cases, compliance and success may be separate considerations. For example, a compensation site may be in compliance with its permit requirements and not be considered a success because it does not replace the functions of the wetland that was lost. On the other hand, a site may fall short of meeting its permit requirements, perhaps because performance standards were unrealistic. The site is therefore not in compliance, yet it may still be determined a success because it compensates for the wetland functions lost.

The second problem involves time; when should a project be evaluated for success? For example, two years after installation a compensation site may not be meeting its performance standards, perhaps because the site has too much bare ground, percent aerial cover of native vegetation is too low, or cover by invasive plant species is too high. The site is, therefore, neither in compliance nor a success. However, looking at the same site five or six years after installation, the site may have experienced rapid growth of native shrubs and trees, native volunteer species may have colonized the bare ground, and maintenance activities may have controlled invasive plants. At this time, the site could be evaluated as a success and considered to be in compliance.

Rather than judging the success or failure of a compensatory wetland mitigation project at a single point in time, Zedler and Callaway (2000) proposed evaluating how a project progresses over time. The authors suggest that a focus on progress would encourage proponents to acknowledge problems occurring at a site and look for solutions. Zedler (2000) proposes that more compensation projects should be viewed as experiments without a specific desired outcome. In lieu of attaining a specific level of performance, projects would be monitored as experiments for at least 25 years. The regulatory framework currently in place, however, does not support this method of evaluation due to the relatively short timeframe allowed for monitoring and assessing the compliance of compensation projects (Breaux and Serefiddin 1999, Zedler 2000).

Refer to Section 6.10.4 for more information on performance standards. Specifically, Section 6.10.4.1 discusses shortcomings of existing performance standards, and Section 6.10.4.3 discusses the need for longer monitoring periods.

6.3.1 Results of Literature Studies

Several studies determined the level of success of compensatory mitigation projects (Table 6-1). Though the data indicated that some projects were successful and some projects were unsuccessful, most compensation projects had an intermediate level of success, meaning they were neither fully successful nor completely unsuccessful.

- 25 to 66% of projects were determined to have an intermediate level of success
- 3 to 43% of projects achieved full success
- 7 to 97% of projects were unsuccessful, though half of the studies found that at least 20% of projects were unsuccessful (Johnson et al. 2002, Michigan Department of Environmental Quality 2000, Mockler et al. 1998, Sudol and Ambrose 2002)

The methods used to evaluate the success of compensatory wetland mitigation projects varied from best professional judgment (Storm and Stellini 1994) to function assessments (Wilson and Mitsch 1996, Balzano et al. 2002), to quantitative measures of vegetation cover and survival (Allen and Feddema 1996), or some combination (Michigan Department of Environmental Quality 2000, Johnson et al. 2002). Though the methods of evaluation differed, most studies considered similar variables such as wetland area, hydrologic conditions, wildlife suitability, vegetation, and soils.

Table 6-1. Results of studies examining the success of compensatory mitigation.

Location of Study	No. of Projects Evaluated	Level of Success	Evaluation Criteria
Washington State (Johnson et al. 2002)	24	13% fully successful 33% moderately successful 33% minimally successful 21% not successful	Wetland acreage, performance standards, goals/objectives, contribution to functions, comparison with wetland lost
Washington/ King County (Mockler et al. 1998)	38	3% successful 97% not successful	Replacing the functions of the wetland lost. Examined vegetation survival and areal coverage, hydrology, soil, wetland and buffer condition assessment, wildlife habitat, and invasive species
Western Washington (Storm and Stellini 1994)	17	23% functioned well ecologically 65% functioned poorly 12% were not completed	Vegetation diversity, non-native plant dominance, structural diversity, wildlife use, adjacent land uses, vegetation cover vs. open water

Location of Study	No. of Projects Evaluated	Level of Success	Evaluation Criteria
Southern California (Allen and Feddema 1996)	75	32 successful 9 mostly successful 10 half successful 5 unsuccessful 8 under construction 5 not initiated 6 did not require mitigation	Project installed according to plan; percent cover of vegetation (dead, living, and invasive)
California/ Orange County (Sudol and Ambrose 2002)	55	16% successful 58% partially successful 26% failures	Qualitative evaluation based on habitat quality (e.g., vegetation density and diversity, invasive species, tree height)
Ohio (Wilson and Mitsch 1996)	5	1 high 2 medium to high 1 medium 1 medium to low	WETII evaluation (Adamus et al. 1989) - hydrology, soils, vegetation, wildlife, water quality
New Jersey (Balzano et al. 2002)	74	Wetland Mitigation Quality Assessment scores were indexed from 0 (low) to 1 (high). The average score was 0.51, and the range was 0.25 to 0.83	Hydrology, soils, vegetation, wildlife suitability, site characteristics, and landscape features
Michigan (Michigan Department of Environmental Quality 2000)	69	22% successful overall 78% unsuccessful overall	Project's legal rating (permit compliance) and biological rating (wetland acreage). Does not include enhancement

6.3.2 Summary of Key Points

- Success is defined as meeting biological or ecological criteria, which may include an assessment of functions.
- The majority of compensatory wetland mitigation projects were found to be neither fully successful nor completely unsuccessful, meaning that most projects had an intermediate level of success, relative to biological or ecological functions.
- Though the methods used to evaluate project success differed, the studies considered similar criteria, such as vegetation, soils, and hydrologic conditions.

6.4 Compliance with Permit Requirements

Regulatory agencies typically require wetland compensation for authorized, unavoidable wetland impacts. A wetland mitigation plan is reviewed and approved as part of the permit approval process. It outlines how wetland impacts will be compensated for. The mitigation plan identifies how the project will be designed. It addresses wetland acreage, hydroperiod, vegetation, goals, objectives, performance standards, monitoring, maintenance, contingency actions, and long-term protection. These are the parameters by which regulators often measure compliance.

According to the Merriam-Webster dictionary, compliance means “conformity in fulfilling official requirements.” Regarding compensatory wetland mitigation, compliance means that a project has satisfied or is satisfying the legal requirements and obligations identified in a permit.

Most studies that examined compliance investigated how well a compensatory wetland mitigation project complied overall (i.e., with all applicable permit requirements). Several of these studies only reported the results of the overall evaluations. Other studies evaluated how well projects complied with individual requirements, such as:

- Installation – whether the project was installed
- Installation according to plan – whether the project was constructed according to the approved mitigation plan and design
- Wetland area establishment – whether the project obtained the acreage of wetland that was required
- Performance standards/goals/objectives attainment – whether the project performed as anticipated
- Monitoring – whether the project was monitored as required (or was required to be monitored)
- Maintenance – whether project maintenance was performed (or required)

Studies also reviewed regulatory follow-up - whether any regulatory agencies made an attempt to track an individual project after the permit was issued.

Each of these types of evaluations is discussed in subsequent sections.

6.4.1 Compliance Overall

Several studies attempted to determine how well a project complied with several or all of its permit requirements. Because permit requirements vary by state and over time, not all compliance evaluations considered the same criteria or requirements. Where specified, the requirements evaluated by a given study are identified in Table 6-2.

Twelve studies evaluated overall compliance with regulatory requirements for compensatory wetland mitigation projects (Table 6-2). In Washington State four studies that evaluated compliance were conducted in the past decade (Storm and Stellini 1994, Mockler et al. 1998, Johnson et al. 2000, Johnson et al. 2002), and two studies were conducted in Oregon (Gwin and Kentula 1990, Shaich and Franklin 1995).

The studies in Washington found that 29% of compensation projects complied with their regulatory requirements. In Oregon, studies revealed that compliance of projects ranged from zero to 36%.

Studies from other states demonstrated more variability in levels of compliance. Results ranged from less than 20% to about 80% of projects in compliance (Holland and Bossert 1994, De Weese 1998, Morgan and Roberts 1999, Michigan Department of Environmental Quality 2000, Brown and Veneman 2001, Balzano et al. 2002, Sudol and Ambrose 2002).

More recent studies (published in 2000 or after) did not report higher levels of compliance than studies conducted in the 1990s. One might therefore assume that compensation projects have not improved over the years. However, it is important to realize that as knowledge of wetland science and compensatory mitigation has improved and evolved, permit requirements have likewise evolved (Kentula 2000). More recent studies may have been evaluating compensation projects that were being held to a higher standard than projects permitted and evaluated in the 1990s (Sudol and Ambrose 2002). However, a study by Cole and Shafer (2002) in Pennsylvania observed that permit requirements had not changed noticeably over the 14-year range of permits they evaluated (1986-1999).

Table 6-2. Level of overall compliance of compensation projects.

Location of Study	No. of Projects Evaluated	% of Projects in Compliance with all Requirements	Evaluation Criteria
Washington (Johnson et al. 2000)	45	29%	• Project installed • Installed according to plan • Meet performance standards
Washington (Johnson et al. 2002)	24	29%	• Establish required wetland acreage • Meet performance standards • Meet goals/objectives
Washington/western (Storm and Stellini 1994) [a]	17	18%	• Installation of both development and compensatory mitigation projects as required

Location of Study	No. of Projects Evaluated	% of Projects in Compliance with all Requirements	Evaluation Criteria
Washington/King County (Mockler et al. 1998)[b]	29 (38)	21% (16%)	• Meet performance standards - vegetation survival, areal cover, invasive species • Design - hydrology, slopes • Installation - soil • Maintenance - mowing, weeding
Oregon/Portland metro area (Shaich and Franklin 1995) [c]	72	36%	• Project installed • Upland buffer area/vegetation requirements • Requirements for timing of project construction • Wetland vegetation requirements • Hydrology requirements • Requirements for water control structures • Fencing requirements
Oregon/Portland metro area (Gwin and Kentula 1990)	11	0%	• Construction plans match permit specs • As-built matches permit specs: wetland area/shape • Actual slopes match planned slopes • Vegetation established as planned
California/ Orange County (Sudol and Ambrose 2002) [d]	57	53%	• Project installed • Meet performance standards/ permit conditions
California/ vernal pools (De Weese 1998)	25	83%	• Attaining performance standards required by Corps
Massachusetts (Brown and Veneman 2001) [e]	109 (7)	43% (100%)	• Project installed • Compensation project of required size • Water inputs sufficient for wetland conditions • At least 75% cover wetland plants (FAC or wetter)
Tennessee (Morgan and Roberts 1999)	50	12%	• Establish required acreage of wetland • Meet performance standards

Location of Study	No. of Projects Evaluated	% of Projects in Compliance with all Requirements	Evaluation Criteria
Michigan (Michigan Department of Environmental Quality 2000) [f]	74	18%	• Mitigation acreage requirement • Implementation of approved mitigation plan • Conservation easement • Submittal of as-built plans • Monitoring • Placement of elevated wildlife structures • Construction schedule with specified completion date • Prohibited actions • Corrective measures identified • Financial assurances
Louisiana (Holland and Bossert 1994)	9	78%	• Meet Corps of Engineers permit conditions
New Jersey (Balzano et al. 2002)[g]	88	48% weighted average	• Grading (56% concurrence) • Hydrology (47% concurrence) • Soil (51% concurrence) • Vegetation cover (39% concurrence) • Vegetation survival (28% concurrence) • Design (56% concurrence)

[a] Compliance not determined for 53% of projects due to lack of information.

[b] 38 projects examined; 9 not completed. Compliance information for 38 projects is in parentheses.

[c] Not all projects had requirements for all criteria (e.g., only 8% had a requirement for fencing).

[d] Calculated from data provided.

[e] 5 projects did not result in wetland impact and were subtracted from the project total. Results were recalculated from the data provided. Parentheses = data for variance projects (received more oversight).

[f] Permit conditions from the criteria list were considered if specified in permit.

[g] Evaluated concurrence with applicable criteria. Percent = average concurrence score for 88 projects. Average concurrence score for each criterion provided in parentheses.

6.4.2 Project Installation

A number of studies investigated whether mitigation projects had even been constructed or installed. In these studies, mitigation projects were either randomly selected from a database or a complete inventory of all projects permitted during a specific timeframe was conducted. Four studies were conducted in Washington. Studies in seven other states, including Oregon, also investigated whether mitigation projects had been installed.

Results indicated that most projects were installed (Table 6-3). The four studies from Washington found that 74 to 93% of compensatory mitigation projects had been installed. Studies from most of the other states showed similar results (64 to 99%). However, studies performed in Florida and Tennessee revealed that less than half of the compensatory wetland mitigation projects had been installed (Erwin 1991, Morgan and Roberts 1999).

Due to the relatively high percentage of projects that were installed, one could assume that the low levels of overall compliance result from inadequate design, installation, maintenance, follow-up, or some combination.

Table 6-3. Percent of compensatory mitigation projects that were installed.

Location of Study	No. of Projects Evaluated	Percent of Projects Installed
Washington (Johnson et al. 2000)	45	93%
Washington/ King County (Mockler et al. 1998)	38	76%
Washington/ western (Storm and Stellini 1994)	17	88%[a]
Washington (Kunz et al. 1988)	35	74%
Oregon/ Portland metro area (Shaich and Franklin 1995)	90	99%
California/ southern (Allen and Feddema 1996)	75	93%
California/ Orange County (Sudol and Ambrose 2002)	57	96%[a]
Michigan (Michigan Department of Environmental Quality 2000)	159	85%
Indiana (Robb 2002)	333	64%
Massachusetts (Brown and Veneman 2001)[b]	109	77%
Tennessee (Morgan and Roberts 1999)	100	47%
Florida (Erwin 1991)	NA	~40% [c]

[a] Calculated from data provided.

[b] Five projects did not result in wetland impact and were subtracted from the project total. Results were recalculated from the data provided.

[c] "Out of more than 100 permitted projects requiring wetland mitigation only 40 had undertaken any mitigation activity."

6.4.3 Installation According to Plan

Another aspect of determining mitigation compliance is evaluating whether a mitigation project has been installed according to its approved plan. When compensatory wetland mitigation is necessary to offset proposed wetland losses, regulatory staff generally require a wetland mitigation plan. The mitigation plan should provide specific information about project construction, including detailed design drawings. Approval of a permit for wetland loss is often contingent upon approval or acceptance of the wetland mitigation plan.

It is commonly assumed that a project will be built exactly as it is designed. However, many factors during construction and installation can influence what is actually built on the ground. Therefore, permit requirements often require (or recommend) submittal of an as-built plan or report that documents the final installed conditions of a site after construction is complete. When available, as-built drawings are used to document the baseline conditions for monitoring of a site.

Three studies evaluated whether compensation projects were installed according to approved plans (Table 6-4). Results from both Washington and New Jersey indicate that more than half of the compensatory mitigation projects were installed according to requirements (Johnson et al. 2000, Balzano et al. 2002). Johnson et al. (2000) found that 55% of the projects were installed to plan. For those that submitted an as-built plan or report, 88% of the projects were installed according to plan. A study in Oregon, however, determined that none of the projects were implemented according to plan (Gwin and Kentula 1990). All three studies mentioned grading and vegetation as the elements of the plan that were not implemented according to the approved plan.

It can be hypothesized that the divergent results noted in the studies above might be the result of an increase of knowledge and expertise over time. For instance, the projects reviewed by Gwin and Kentula (1990) were designed, permitted, and constructed in the early 1980s. Since that time much has been learned by those who design, construct, and regulate compensatory mitigation projects. It is possible that improved designs, experience and skill in implementing the designs, and improved regulatory follow-up have resulted in a higher percentage of projects being installed according to plan by the mid- to late 1990s. The current scientific literature does not address this possibility.

Table 6-4. Percent of compensatory mitigation projects installed according to plan.

Location of Study and Reference No.	No. of Projects Evaluated	Percent Installed to Plan	Aspects Not Installed to Plan
Washington (Johnson et al. 2000)	42	55%	Mainly vegetation, also grading, misc. plan elements (e.g., fences, signs)
Oregon/ Portland metro area (Gwin and Kentula 1990)	11	0%	Size, shape, slopes, and vegetation
New Jersey (Balzano et al. 2002)	88	56%	Incorrect elevations, sizes, and/or shapes

6.4.4 Establishment of Wetland Acreage

Compensatory wetland mitigation projects are intended to compensate for the loss of wetland area and functions. Hence, permits and mitigation plans often identify a specific acreage of compensation required to offset those losses. Establishing the required acreage is therefore an important criterion of regulatory compliance. (Functions provided by compensatory mitigation projects are discussed in Section 6.8.)

Thirteen studies examined compensatory wetland mitigation sites to determine if the acreage of wetlands required by the permits had been established (Table 6-5). The studies presented the data from these investigations in two ways.

- **The percentage of projects establishing the required wetland acreage.** Researchers determined if each project met its required wetland acreage, then reported how many projects actually met the wetland acreage requirement as a percentage of the total number of projects considered. A few studies mentioned a specific threshold, such that a project had to be smaller than required by a specific acreage or percentage in order to fail to meet its wetland area (Brown and Veneman 2001, Johnson et al. 2002, Morgan and Roberts 2003).
- **The percentage of compensatory wetland acreage established.** Researchers determined the total acreage of compensatory mitigation that was verified as wetland for all the projects considered. The study then reported the total acreage of wetland compensation that was established as a percentage of the total acreage that was required for all the projects considered.

Over half of projects achieved the required wetland area in Washington and Oregon (Shaich and Franklin 1995, Johnson et al. 2002). In fact, the majority of studies determined that about half of the compensation projects established the required acreage of wetland. However, three studies found that less than 30% of projects met their acreage requirements (McKinstry and Anderson 1994, Balzano et al. 2002, Morgan and Roberts 2003). In New Jersey only 7% of projects achieved the wetland acreage requirements (Balzano et al. 2002).

For the total acreage of wetland achieved versus required, a study from Washington determined that 84% of the required acreage of compensatory wetlands was established (Johnson et al. 2002), while a study in Oregon found about 70% of the required wetland acreage was established (Gwin and Kentula 1990). Results from other states indicated between 44 and 74% of the required wetland acreage had been established.

Why is there a discrepancy between the percent of projects achieving acreage and the percentage of total acreage established? New Jersey, for example, found that only 7% of compensation projects achieved the required wetland acreage, yet 63% of the total required wetland acreage was established. It can be hypothesized that this is due to small, individual projects that establish a portion of the required acreage but fall short of the total amount required. For example, a site that was required to provide 1 acre of mitigation but only provided 0.8 acre would not meet the acreage criteria. However, the 0.2-acre difference may represent a very small fraction of the total acreage of compensation evaluated for a large study, thereby affecting the total acreage percentage very little.

Table 6-5. Establishment of required wetland acreage.

Location of Study	No. of Projects Evaluated	% of Projects Achieving Required Wetland Area	% of Required Wetland Area that Was Established
Washington (Johnson et al. 2002)[a]	24	58%	84%
Oregon/Portland metro area (Shaich and Franklin 1995)[b]	72	53% [e]	NA
Oregon/Portland metro area (Gwin and Kentula 1990)	11	NA	71%
California/southern (Allen and Feddema 1996)[c]	75	NA	69%
California/Orange County (Sudol and Ambrose 2002)	55	52%	NA
Wyoming (McKinstry and Anderson 1994)	64	14% [e]	NA
New Jersey (Balzano et al. 2002)	85	7%	63%
Tennessee (Morgan and Roberts 1999)	50	28%	68%
Ohio (Wilson and Mitsch 1996)	5	40%	66%
Indiana (Robb 2002)	31	NA	44%
Michigan (Michigan Department of Environmental Quality 2000)	159	50%	NA
Massachusetts (Brown and Veneman 2001)[d]	109	46%	NA
Florida (Erwin 1991)	NA	NA	74%

NA= information not available

[a] West of the Cascades, projects established 92% of the required acreage; east side projects established 25% of the required acreage.

[b] Compensation wetlands were 16 acres (6.5 ha) short of the 69 acres required.

[c] Projects > 8.5 acres (3.4 ha) resulted in a net gain of 17 acres (6.9 ha) of wetland area, while projects < 8.5 acres resulted in a net loss of almost 25 acres (10 ha).

[d] Five projects did not result in wetland impact and were subtracted from the project total. Results were recalculated from the data provided.

[e] Calculated from data provided.

6.4.5 Attainment of Goals, Objectives, and Performance Standards

Another critical component of compliance for a compensatory wetland mitigation project is determining whether the project has met its goals, objectives, and/or performance standards. Goals, objectives, and performance standards are generally included as part of an approved wetland mitigation plan. Goals and objectives are intended to provide a blueprint for what the project proposes to accomplish in terms of anticipated wetland type, specific habitat, functions, and/or values. The performance standards are intended to provide measurable criteria to determine if the project has accomplished its goals and objectives (Hruby et al. 1994, Ossinger 1999).

Two separate factors were investigated in the studies reviewed:

- Whether a project had goals, objectives, and performance standards
- Whether projects were meeting their goals, objectives, and performance standards

Data in Table 6-6 indicate that at least three-quarters of projects had goals, objectives, or both (Erwin 1991, Storm and Stellini 1994, Johnson et al. 2002). However, fewer projects met the goals/objectives (10 to 38%) according to the two studies that reported this information (Erwin 1991, Johnson et al. 2002).

In general, performance standards were specified less frequently than goals and objectives, though at least half of the projects had them (Erwin 1991, Storm and Stellini 1994, Mockler et al. 1998, Johnson et al. 2000, Cole and Shafer 2002). Two studies conducted in Washington determined that 21% of projects met their performance standards (Mockler et al. 1998, Johnson et al. 2002), while a third study from Washington found that 35% of projects met performance standards (Johnson et al. 2000).

A review of the articles suggests that the percent of projects with performance standards increased with more recent projects. For example, Storm and Stellini (1994) and Cole and Shafer (2002) evaluated compensation projects that were permitted in the mid to late 1980s or early 1990s. Performance standards may not have been as rigorously required (Cole and Shafer 2002) or they may not have been specifically identified as performance standards. For example, of 10 projects that did not contain performance standards, 30% were permitted in the late 1980s and 80% were permitted prior to 1995, while 20% were permitted in the late 1990s (Cole and Shafer 2002).

Data suggest (Table 6-6) that the more recent projects did not appear any more likely to meet performance standards than earlier projects (Mockler et al. 1998, Johnson et al. 2000, Cole and Shafer 2002, Johnson et al. 2002). Some believe that performance standards have become more rigorous overtime, and more recent projects have been held to a higher standard. Cole and Shafer (2002), however, did not find that performance standards noticeably changed in terms of content from projects permitted in the late 1980s to the late 1990s. Therefore, one can conclude that the year of permitting does not appear to be a factor in whether projects met their performance standards.

More information on performance standards is provided in Section 6.10.4.

Table 6-6. Attainment of goals, objectives, and performance standards.

Location of Study	No. of Projects Evaluated	% of Projects w/ Goals or Objectives	% of Projects w/ Performance Standards	% of Projects Meeting Goals or Objectives	% of Projects Meeting Performance Standards
Washington (Johnson et al. 2000)	34	NA	87%[a]	NA	35%
Washington (Johnson et al. 2002)	24	92%	NA	38%	21%
Washington/ King County (Mockler et al. 1998)	29	NA	100%	NA	21%
Washington/ western (Storm and Stellini 1994)	17	76%	53%	NA	NA
Pennsylvania (Cole and Shafer 2002)	23	NA	57%	NA	62%
Florida (Erwin 1991)	40	85%	60%	10%	NA

NA = information not available.

[a] Calculated from data provided.

6.4.6 Monitoring

To determine if a compensatory wetland mitigation project is in compliance, it is necessary to monitor the project over time. Monitoring requirements are typically identified in the wetland mitigation plan. The duration, frequency, and methods of monitoring should depend on the goals, objectives, and performance standards for the project.

Monitoring is the process through which data about site conditions is gathered. Monitoring data is used to determine whether a project is achieving its performance standards, and therefore its goals and objectives, within a predicted timeframe. Monitoring also provides critical information about whether a site requires maintenance or contingency actions. Monitoring is therefore essential for a project to achieve compliance.

The studies investigating whether compensatory wetland mitigation projects were required to be monitored and whether monitoring actually occurred are summarized in Table 6-7. In general, studies conducted more recently found that monitoring was required for a greater percentage of projects. Data from four studies indicate monitoring was required for at least three-fourths of projects (Erwin 1991, Morgan and Roberts 1999, Johnson et al. 2000, Michigan Department of Environmental Quality 2000). The remaining two studies, which examined compensation projects permitted in the late 1980s and early 1990s, found that monitoring was required for a third to half of projects (Holland and Kentula 1992, Storm and Stellini 1994).

Less than half of the projects had monitoring data. However, the studies did not determine whether the monitoring was not conducted or whether there was simply no record of the monitoring reports on file with the regulatory agencies. Since over half of the studies mentioned difficulty finding complete project information from the agency files (Storm and Stellini 1994, Morgan and Roberts 1999, Johnson et al. 2000, Cole and Shaffer 2002), it is possible to conclude that monitoring reports may have been submitted to the appropriate agencies but the reports were lost due to a lack of follow-up and poor file maintenance. If monitoring is not conducted there is no means to trigger maintenance or contingency actions. The consequence of inadequate follow-up by regulatory agencies is discussed in Section 6.4.8.

Table 6-7. Percent of projects requiring monitoring and those actually monitored.

Location of Study	% of Projects Requiring Monitoring	% of Projects Monitored
Washington (Johnson et al. 2000)	71%	33%
Washington/ western (Storm and Stellini 1994)	53%	18%
California (Holland and Kentula 1992)	32%	NA
Michigan (Michigan Department of Environmental Quality 2000)	87%	35%
Pennsylvania (Cole and Shafer 2002)	NA	<10%
Tennessee (Morgan and Roberts 1999)	89%	43%
Florida (Erwin 1991)	98%	38%[a] (62%)[b]

[a] Represents projects that were adequately monitored.

[b] Calculated from Erwin (1991) indicating all projects that received some level of monitoring.

6.4.7 Maintenance

Compensatory wetland mitigation sites require maintenance to help ensure that goals and performance standards will be achieved. Maintenance includes implementing corrective actions to rectify problems, such as an insufficient water supply or inappropriate water regime, invasive species infestation (e.g., reed canarygrass, bull frogs), trash, vandalism, or anything else that may result in non-compliance with permit requirements. Johnson et al. (2002) observed that a lack of maintenance was one of the main reasons for poor success of mitigation projects.

Results revealed that permitting agencies did not require all compensation projects to provide maintenance. Studies discovered that permits required site maintenance for 41 to 78% of projects (Erwin 1991, Storm and Stellini 1994, Michigan Department of Environmental Quality 2000). However, even fewer projects (20 to 60%) complied with their maintenance requirements (Erwin 1991, Michigan Department of Environmental Quality 2000).

The research did not investigate the reasons for low compliance with maintenance provisions. One may assume that it is linked to inadequate monitoring, lack of regulatory follow-up, or a lack of cooperation from the owner of the site.

6.4.8 Regulatory Follow-Up

Once compensatory wetland mitigation is required, it is the responsibility of the regulatory agencies to track the project over time and determine if it complies with permit requirements. A regulatory agency follows up on compensatory mitigation projects by:

- Ensuring that the compensation project is constructed as designed and approved, or that the applicant documents, through "as-built" reports why approved plans were modified during installation
- Ensuring that required monitoring reports are submitted on schedule
- Performing site visits to confirm monitoring results and attainment of performance standards
- Ensuring maintenance actions are undertaken on schedule
- Ensuring that appropriate contingency measures are enacted
- Ensuring the compensation site is protected over the long-term (i.e. through a legal protection mechanism such as a conservation easement)

Studies in Washington and Oregon indicated that about half of compensatory wetland mitigation projects received some regulatory follow-up in the form of site visits, phone calls, or letters (Kentula et al. 1992, Johnson et al. 2002). In Michigan only about a quarter of projects received any kind of follow-up after the permit was issued (Michigan Department of Environmental Quality 2000).

A few studies also examined the effect of regulatory follow-up on project compliance, success, or both. Robb (2002) alluded to the fact that the high number of non-compliant compensation projects resulted from a lack of follow-up and enforcement actions. In Washington a study noted that all of the projects lacking regulatory follow-up were either minimally or not successful, while two-thirds of the projects receiving some kind of follow-up were either fully or moderately successful (Johnson et al. 2002).

One team of researchers observed:

> *The most ecologically successful sites were generally those that had received follow-up work in the form of maintenance, replanting, or improvements to grading or water control structures in accordance with recommendations made by NJDEP [New Jersey Department of Environmental Protection] and other regulatory agencies after initial compliance inspections revealed problems* (Balzano et al. 2002).

Studies indicated that regulatory follow-up can help to ensure the success of compensation sites (Johnson et al. 2002, Balzano et al. 2002). It is assumed that applicants will be more likely to abide by permit requirements and submit monitoring reports if regulatory agencies are actively following up on projects. Since monitoring reports are meant to identify what is working and where there are shortfalls, maintenance actions can be initiated or contingency measures can be triggered to correct the shortfalls and problems as soon as possible. Therefore, one can conclude that agency follow-up improves the compliance and success of compensation projects.

6.4.9 Summary of Key Points

- Most compensatory wetland mitigation projects were installed. However, compliance levels overall were generally low.
- Two out of three studies found that more than half of projects were installed according to plan. Projects not installed to plan most often did not comply with grading and vegetation requirements.
- The majority of studies found that about 50% of projects achieved their required wetland acreage.
- Even if individual projects did not fully achieve their required acreage, most studies found that at least 66% of the overall required acreage of compensation had been established.

- The requirement for monitoring as a regulatory condition seems to be increasing in more recent studies (30 to 50% in the early 1980s; 75% in more recent studies).
- Over 50% of the studies noted that it was difficult to find complete project files, thereby making it difficult to document if monitoring was occurring or being tracked by regulatory staff.
- The research found that 41 to 78% of projects required maintenance; however, only 20 to 60% of projects complied with maintenance requirements.
- Studies in Washington and Oregon found that approximately half of projects received some regulatory follow-up.
- Two studies suggested that follow-up had a positive influence on the level of compliance and success for compensatory wetland mitigation projects.

How is compensatory wetland mitigation doing in Washington?*

Five studies of compensatory wetland mitigation have focused on projects in Washington State during the past decade[1]. The studies examined success, ecological functioning, permit compliance, and achievement of required wetland area, though not all studies looked at the same factors in the same way. The results suggest that compensatory mitigation in Washington is neither fully successful nor completely unsuccessful.

Most studies found that less than half of wetland compensation projects are fully effective. In the most recent and comprehensive evaluation of compensation projects, Johnson et al. (2002) found that 13% of compensatory wetland mitigation projects were fully successful and 33% were moderately successful. In western Washington, Storm and Stellini (1994) determined that 24% of compensation projects functioned well. In King County, Mockler et al. (1998) indicated that 3% of projects replaced lost wetland functions.

In terms of compliance, Johnson et al. (2000) determined that 29% of projects were in full compliance, while for King County Mockler et al. (1998) found that 21% of projects were meeting their required performance standards.

Kentula et al. (1992) examined Section 404 permit decisions for Washington from 1980 through 1986. Data indicated that permit decisions resulted in a wetland loss of 40 acres (16 ha). Johnson et al. (2002) determined that 24 acres (10 ha) of wetland were lost due to projects that did not successfully establish wetland area and the frequent use of existing wetlands for enhancement.

[1]All studies, except Kentula et al. (1992), sampled a sub-set of the applicable mitigation projects.
*Results have been simplified for this summary. Please refer to Sections 6.3 and 6.4 for complete information.

6.5 Types of Compensatory Mitigation

When discussing compensatory mitigation it is important to have a common understanding of the types of compensation that can be used to mitigate for wetland losses. This is difficult because various agencies and organizations often define types of compensation differently (Morgan and Roberts 1999). An added difficulty is that each type of compensation represents a range of activities on a continuum rather than a distinct procedure.

This section describes several types of compensatory mitigation:

- Restoration
- Creation
- Enhancement/exchange
- Preservation
- Mixed compensatory mitigation
- Wetland mitigation banking
- In-lieu fee programs

Definitions given to each of the mitigation types are discussed below, followed by a description of how frequently each type is used and its relative effectiveness.

6.5.1 Restoration

Of the types of compensation, restoration has the widest variety of definitions. The most general is the reestablishment of wetland conditions (i.e., area, functions, and values) at a location where they formerly existed but no longer exist (Johnson et al. 2000, Jones and Boyd 2000). Activities associated with this definition could include removing fill material, plugging ditches, or breaking drain tiles. Other definitions involve returning a site to some historic condition. The following are examples of other definitions.

- Re-establishing historic hydrologic processes (National Research Council 2001) or hydrogeomorphic (HGM) classes (Johnson et al. 2000). Activities associated with this definition typically involve removing a levee or breaching a dike to reconnect an area to the floodplain or to tidal influence.
- "Return of an ecosystem to a close approximation of its condition prior to disturbance (NRC 1992). Restoration requires knowledge of the wetland type prior to disturbance and has the goal of returning the wetland to that type" (Gwin et al. 1999).
- Returning an altered wetland "to a previous, although altered condition (Lewis 1990)" (Gwin et al. 1999).
- "The process, or the result of the process of returning an area or ecosystem to some specific former condition" (Munro 1991).

Perhaps as a result of the numerous definitions, confusion about what constitutes restoration versus other types of compensatory mitigation can occur in regulatory permits and mitigation plans. The last three definitions in the list above could just as easily describe enhancement activities. For example, planting trees in a degraded wet pasture, often considered enhancement, could be an attempt to return an ecosystem (the pasture) to an approximation of its prior condition (forested wetland).

In their study of compensatory wetland mitigation projects in Tennessee, Morgan and Roberts (1999) mentioned that several projects were classified as restoration. Based on the activities specified, however, enhancement would have been a more appropriate term. Similar confusion occurred between restoration and creation. As a result of this confusion, the effectiveness of restoration, as a type of compensation, is difficult to assess.

6.5.1.1 Use of Restoration

For compensatory mitigation, restoration is often cited as the highest priority or most recommended type of compensation "because it offers the highest probability of success (Kruczynski 1990, Kusler and Kentula 1990, USDA-SCS 1992)" (Morgan and Roberts 1999). In addition, the National Academy of Sciences recommended restoration over creation. "Restoration of wetlands has been observed to be more feasible and sustainable than creation of wetlands" (National Research Council 2001).

This emphasis on restoration is not reflected in the number of freshwater, compensatory restoration projects implemented on the ground. Restoration tends to be one of the least utilized types of compensation (Jones and Boyd 2000). In fact, two studies mentioned that none of the projects involved restoration (Shaich and Franklin 1995, Gwin et al. 1999). Most of the studies that specifically mentioned the number or percentage of projects using a particular type of compensation found that 20 to 30% of projects involved some restoration of wetland acreage (Morgan and Roberts 1999, Johnson et al. 2000, Johnson et al. 2002). Projects employing restoration as the sole form of compensation are even fewer (Shaich and Franklin 1995, Johnson et al. 2000, Johnson et al. 2002).

In a departure from the other studies, Holland and Kentula (1992) found that 65% of permits required restoration. However, 42% of the compensatory wetlands they looked at were estuarine or marine. If estuarine and marine projects are subtracted, the percentage of restored, freshwater wetlands is similar to the other studies.

Morgan and Roberts (1999) suggest that the lack of compensatory wetland restoration projects is due to the fact that "most suitable restoration sites are 'prior converted' farmland and because sizable acreages are being restored under the Wetland Reserve Program . . . sites available for compensatory mitigation may be limited." In Washington, however, the authors of Volume 1 believe that restoration is used infrequently because most wetland impacts are relatively small (less than 2 acres [0.8 ha]), and it is very difficult to find restoration opportunities for small sites that are not cost prohibitive. Restoration is typically most feasible and cost effective if done over a large area. In addition, some regulatory requirements, particularly for local governments, direct applicants to provide compensation on-site, which often precludes an opportunity for restoration.

6.5.1.2 Effectiveness of Restoration

While it is widely stated that restoration is the most effective approach, the data to substantiate this claim are sparse. Studies indicate that there is a limited use of restoration for compensatory mitigation in freshwater wetlands. Thus, there is a substantial lack of data with which to evaluate its effectiveness as a type of compensation.

In Washington Johnson et al. (2000) found that one of three restoration projects was in full compliance. Johnson et al. (2002) found that one of two restoration projects established the required acreage of wetland and was fully successful. In Florida, Erwin (1991) found that restoration successfully established 88 acres (36 ha) more wetland area than was required. The limited existing data appear to suggest that when wetlands are restored, they are relatively effective at compensating for permitted losses.

6.5.2 Creation

It is generally agreed that creation involves establishing wetland conditions (area, functions, and values) in a location where wetland conditions previously did not exist (Johnson et al. 2000) or "that was not a wetland in the recent past (within the last 100-200 years) (Kruczynski 1990, Lewis 1990)" (Gwin et al. 1999). "Typically, a wetland is created by excavation of upland soils to elevations that will support the growth of wetland species through the establishment of an appropriate hydroperiod (Kruczynski 1990, Lewis 1990)" (Gwin et al. 1999).

Gwin et al. (1999) made a distinction between creating a wetland that is isolated from existing wetlands (creation) and creating a wetland that is immediately adjacent to an existing wetland, thereby enlarging the existing wetland (expansion). No other studies made this distinction.

> The U.S. Army Corps of Engineers' Regulatory Guidance Letter -02-2 uses the term *establishment* rather than the previously accepted term *creation*. Federal agencies, as well as the Department of Ecology, have started using the term *establishment*. However, this document synthesizes studies and documents written before this regulatory guidance letter was produced. Therefore, this document uses the term *creation* rather than *establishment*.

6.5.2.1 Use of Creation

Seven studies discussed how frequently creation was required as compensation. All noted that at least 30% and in some cases more than half of compensatory wetland projects were created or involved some creation (Holland and Kentula 1992, Shaich and Franklin 1995, Gwin et al. 1999, Morgan and Roberts 1999, Johnson et al. 2000, Jones and Boyd 2000, Johnson et al. 2002).

6.5.2.2 Effectiveness of Creation

In Washington, Johnson et al. (2000) found that 10% of created wetlands were in compliance. Seventy percent of creation projects established the required acreage of wetland, and 60% of created projects were either fully or moderately successful (Johnson et al. 2002).

In other states, however, created wetlands did not perform as well. Creation projects failed to establish 527 acres (213 ha) of required wetland area in Florida (Erwin 1991). In Tennessee, Morgan and Roberts (1999) found, "Most creation projects…were only partially successful because they failed to develop wetland characteristics throughout… Problems with created wetlands were numerous and involved both site design and vegetation establishment."

The results on the effectiveness of creation are mixed. Though projects in Washington have poor compliance, other aspects of effectiveness are relatively good. However, other states found poor effectiveness for created wetlands. The data therefore suggest that further study is warranted.

6.5.3 Enhancement/Exchange

Enhancement involves modifying a specific structural feature of an existing degraded wetland to improve one or more functions or values based on management objectives (Gwin et al. 1999, Johnson et al. 2000). Enhancement typically consists of:

- Planting vegetation
- Controlling non-native, invasive species
- Modifying site elevations or the proportion of open water to influence hydroperiods

Gwin et al. (1999) defined exchange as:

> *Enhancement taken to the extreme (Kruczynski 1990), with most or all of the wetland converted from one type to a different type. For example, resource managers may intend to enhance habitat value for waterfowl by excavating an area of open water within an existing emergent marsh. However, if the open water area replaces the emergent wetland or a large proportion of it, wetland types have been exchanged.*

Because enhancement involves altering an existing wetland to compensate for the loss of other wetlands, the scientific literature mentions three main concerns regarding its use.

- Enhancement fails to replace lost wetland area (Shaich and Franklin 1995, Morgan and Roberts 1999). For this reason, the state of Michigan does not allow the use of enhancement for compensatory mitigation (Michigan Department of Environmental Quality 2000).

- Enhancement may fail to replace wetland functions, since "a positive change in one wetland function may negatively affect other wetland functions (Kruczynski 1990, Lewis 1990)" (Gwin et al. 1999). In addition, "there commonly is disagreement about whether or not the practice implemented actually enhances conditions at a site" (Morgan and Roberts 1999).

- Enhancement may result in a conversion of HGM and/or Cowardin classes, typically producing a compensation wetland without natural analogues (Shaich and Franklin 1995, Gwin et al. 1999, Johnson et al. 2002). When enhancement is used for compensation in such cases:

  A single Section 404 decision results in the destruction of the wetland for which the permit was issued, along with the conversion of a second wetland to a different, often atypical, HGM type. This 'double whammy' means that exchange [enhancement] *explicitly does not fulfill the objective of 'no-net-loss' of wetlands but, instead, ensures loss of wetland area, additional wetland disturbance, and changes in overall ecological function* (Gwin et al. 1999).

6.5.3.1 Use of Enhancement

Studies indicated that more than one-third of compensation projects used enhancement of existing wetlands as compensatory mitigation (Shaich and Franklin 1995, Gwin et al. 1999, Morgan and Roberts 1999, Johnson et al. 2000, Johnson et al. 2002).

6.5.3.2 Effectiveness of Enhancement

The effectiveness of enhanced compensation wetlands was evaluated by only two studies, both conducted in Washington. The researchers found less than 13% of enhanced wetlands were in complete compliance, while 56% of enhanced wetland projects met the requirement for acreage of compensation. (For projects that proposed to enhance existing wetlands, establishing the required acreage of wetland compensation entailed implementing the proposed actions to enhance the mitigation site.) Furthermore, none of the enhanced compensation wetlands were fully successful, while 89% were minimally or not successful (Johnson et al. 2000, 2002). For more information refer to Section 6.3.1 and Table 6-1.

Johnson et al. (2002) suggested two main reasons for the low level of success among enhancement projects.

- The enhancement project did not achieve the proposed vegetative structure, diversity, or both (the planted trees and shrubs did not survive or did not grow). Thus the project did not establish the required acreage of compensation, did not meet performance standards, or both.

- The enhancement project achieved the proposed structure/diversity, but despite this, it did not adequately compensate for the wetlands lost because the contribution of the enhancement to the performance of wetland functions was low.

The enhanced wetlands evaluated by Johnson et al. (2002) were all in the ground for less than eight years. Their study confirmed that for the projects they evaluated, eight years was not sufficient time to achieve the structural and species complexity of shrub and forested habitats. When structurally complex habitats are the goal of a compensatory mitigation design, studies continue to show that longer timeframes are necessary to begin to provide some of the attributes of those functions (National Research Council 2001). If structurally complex habitats are altered, it is possible to conclude that the delay in replicating those functions results in a prolonged temporal loss of functions on the landscape. This is equally true for projects proposing to restore or create wetlands.

Wetland creation vs. enhancement: Which contributes greater functions?

Johnson et al. (2002) determined that created wetlands were significantly more successful than enhanced wetlands. These researchers assessed the potential of compensation wetlands to perform wetland functions. They then determined how much the activities associated with the type of compensation contributed to, or improved, the level of wetland function. For creation/restoration projects it was assumed that if wetland conditions were achieved then the compensation activities were responsible for providing the assessed level of wetland functions. Enhanced wetlands performed some wetland functions prior to implementation of compensation activities. The authors believed it was important to determine how much enhancement activities contributed to, or improved, the level of performance of functions at a compensation wetland. The authors believed this was particularly important since enhancement, as a compensation tool, is based on improvement of wetland functions.

The study compared the contribution of created sites and enhanced sites for three function categories. Results indicated that over half of the created sites provided high or moderate contributions to wildlife habitat, water quality, and water quantity functions. Over half of the enhancement projects provided minimal to no contribution to wetland functions. The vast majority of enhancement actions were targeted at improving wildlife habitat functions. However, the enhanced wetlands were typically surrounded by development and lacked the buffers and connectivity necessary to improve habitat for most wildlife. In addition, most of the wetlands that were enhanced already provided some water quality functions. Thus, creation of wetlands provided a significantly greater contribution to the performance of water quality functions than enhancement of wetlands. Contribution to wetland functions was one element of overall success.

It is important to note that many created wetlands and some enhanced wetlands resulted in Cowardin and hydrogeomorphic (HGM) classes that were not typical for the landscape. This is discussed in more detail in Sections 6.8.2.2 and 6.8.5.1, respectively. Also, because enhancement provides less gain in function per acre than creation or restoration, replacement ratios are generally higher; refer to Section 6.6 for more information.

6.5.4 Preservation

Preservation means "the protection of an existing and well-functioning wetland from prospective future threats" (National Research Council 2001). Preservation, therefore, provides the opportunity to protect wetland areas that might otherwise be in jeopardy. Like enhancement, preservation does not produce any new wetland acreage; for that reason, some concerns have been raised regarding its use as compensation for permitted wetland loss.

- Preservation results in a net loss of wetland acreage.
- Preserved wetlands are generally not large enough to protect ecosystems and biodiversity over the long term (Whigham 1999).
- Preserved areas may not be checked by regulatory agencies to verify that they contain the specified acreage of wetland. For example, Morgan and Roberts (1999) observed that one of the larger preserved wetlands in their study was predominantly upland and "did not meet the criteria for being considered a jurisdictional wetland."

On the other hand, if an area can be verified as wetland, "Preservation of an existing wetland removes the uncertainty of success inherent in a wetland creation or restoration project and requires no construction to complete" (Washington State Department of Transportation 1999). Preservation, therefore, eliminates the risk of failure and temporal loss of wetland functions since the preserved area is already an existing wetland.

6.5.4.1 Use of Preservation

The studies generally found that preservation was required as compensation for less than one-quarter of projects (Holland and Kentula 1992, Morgan and Roberts 1999, Johnson et al. 2000, Jones and Boyd 2000). Preservation generated about 2% of the compensatory wetland acreage in a study from San Francisco, California (Breaux and Serefiddin 1999). A report from the Washington State Department of Transportation (1999) indicated that 76% of state transportation departments in the United States use preservation as at least one component of compensatory mitigation and 38% use it as a stand-alone form of compensation.

6.5.4.2 Effectiveness of Preservation

There is a general lack of information about the effectiveness of preservation. Only one study examined the effectiveness of preservation as a type of compensatory mitigation. In Washington, Johnson et al. (2000) determined that all four of the projects involving preservation as the sole form of compensation were in compliance. Compliance for preservation projects entailed verifying that the area was preserved and free from development and that a deed restriction or conservation easement was in place to legally protect the parcel from future development.

6.5.5 Mixed Compensatory Mitigation

Mixed projects involve more than one type of compensatory mitigation. For example, a common proposal in the Pacific Northwest entails enhancing an existing wetland and creating additional wetland area immediately adjacent to it. Mockler et al. (1998) observed, "most sites consist of creation—a small pool graded for open water and emergents—and enhancement, typically of wetland buffer." Mixed compensation, however, can also occur on separate sites, such as a created wetland adjacent to the development site and a preserved wetland some distance away.

Several studies identified mixed compensation projects (Mockler et al. 1998, Gwin et al. 1999, Johnson et al. 2000, Johnson et al. 2002). For their studies of compensation wetlands, Mockler et al. (1998) and Johnson et al. (2002) classified compensation wetlands according to their dominant type of compensation. However, some projects lacked sufficient information to make this determination, while other projects lacked dominance by any one type of compensation.

6.5.5.1 Use of Mixed Compensation Projects

In the six studies that discussed how frequently mixed compensatory mitigation was required, results ranged from 13% (Johnson et al. 2002) to 43% (Johnson et al. 2000). Most studies found that mixtures were used for less than a third of projects (Holland and Kentula 1992, Shaich and Franklin 1995, Gwin et al. 1999, Morgan and Roberts 1999).

6.5.5.2 Effectiveness of Mixed Compensation Projects

Only two studies, both from Washington, examined the effectiveness of projects utilizing a mixture of compensation types. Johnson et al. (2000) found that 32% of mixed projects were in compliance. Johnson et al. (2002) determined that all of the mixed projects were moderately successful.

6.5.6 Wetland Mitigation Banking

Mitigation banking is defined as "the practice of restoring, creating, enhancing, or preserving off-site wetland areas to provide compensatory mitigation for authorized impacts to wetlands" (Environmental Law Institute 2002). Wetland banking provides an alternative to traditional, concurrent, compensatory wetland mitigation, and its acceptance and use continue to grow.

Typically a public agency, organization, or private entrepreneur establishes a bank on a large area to be used to compensate for a number of smaller wetland impacts. Banks are generally established as compensation in advance of authorized impacts to wetlands at another site. One may conclude that this practice could provide advantages over traditional compensatory mitigation by reducing the temporal loss of wetland functions.

6.5.6.1 Use of Wetland Banking

Mitigation banking was used for about 7% of Section 404 permits in California issued from 1971 to 1987 (Holland and Kentula 1992). For permits issued from 1996 to 1998 which required mitigation, the Corps District of Norfolk, Virginia reported about 10% of projects purchased bank credits for use as compensation (Jones and Boyd 2000).

By the beginning of 1996, Brown and Lant (1999) determined that 68 banks had been established across the country, totaling nearly 41,000 acres (16,590 ha). A recent survey by the Environmental Law Institute (2002) determined that 219 banks had been approved across 40 states, totaling more than 139,000 acres (56,250 ha). Though 22 of the 219 banks have already sold all their eligible compensatory wetland acreage/credits, the remaining 197 banks were active, meaning they had credits/acreage that had not yet been purchased for use as compensation (Environmental Law Institute 2002).

Since wetland bank credits result from one or more of the previously mentioned types of compensation, the Environmental Law Institute (2002) investigated how frequently each type was used in mitigation banking. Results indicated that 78% of banks involved multiple types of compensation and that enhancement and restoration are the most commonly used. Of the banks that relied on a single type of compensation, about a third was restoration; another third was creation, while enhancement and preservation were each used on 16% of the banks.

6.5.6.2 Effectiveness of Wetland Mitigation Banks

Only one study has examined the effectiveness of wetland mitigation banks. Brown and Lant (1999) examined banks that had been established by the beginning of 1996. Overall, they found there would be a net loss of over 21,000 acres (8,450 ha) of wetland due to the use of enhancement and preservation at banks. The authors also discovered that eight banks did not provide the functions required or specified, while four banks used or sold more acreage for compensation of wetland loss than was eligible from the bank (in other words, the bank was overdrawn).

Wetland mitigation banking is increasingly being used to compensate for wetland losses. Yet the only study investigating the effectiveness of banks raises concerns about its use. Further study will therefore be critical to determine the level of compliance and success of mitigation banks in providing functions.

Please refer to Section 6.10.6 Mitigation Banking for more information on wetland banking as it relates to improving compensatory mitigation. In addition, the *Draft Programmatic Environmental Impact Statement: Washington State's Draft Rule on Wetland Mitigation Banking* (Driscoll and Granger 2001) contains a more in-depth discussion of the issues involved in mitigation banking (available at: http://www.ecy.wa.gov/biblio/0106022.html).

6.5.7 In-Lieu Fee Programs

In-lieu fee programs provide an additional option for compensatory mitigation. They allow permit applicants to compensate for wetland losses by paying a fee to a third party such as a government agency or conservation organization (U.S. General Accounting Office 2001, Environmental Law Institute 2002). The fees are intended to be used to restore, create, enhance, or preserve wetlands (U.S. General Accounting Office 2001).

Generally, in-lieu fee contributions are collected in advance of wetland losses. These funds are accumulated until they are sufficient to design and implement a wetland compensation project (Environmental Law Institute 2002).

6.5.7.1 Use of In-Lieu Fee Programs

A recent survey by the Environmental Law Institute (2002) determined there were 87 active in-lieu fee programs across 27 states. "Through fiscal year 2000, developers used the in-lieu-fee option to fulfill mitigation requirements for over 1,440 acres [583 ha] of adversely affected wetlands, and paid over $64.2 million to in-lieu-fee organizations" (U.S. General Accounting Office 2001).

6.5.7.2 Effectiveness of In-Lieu Fee Programs

Two studies discussed the effectiveness of in-lieu fee programs. However, neither study provided information on the level of compliance or ecological success of these programs.

A study by the U.S. General Accounting Office (2001) examined the effectiveness of in-lieu fee programs used by the U.S. Army Corps of Engineers (Corps) to compensate for wetland losses permitted through the Section 404 program. Of the 17 Corps districts using in-lieu fees, 65% did not require a specific timeframe for spending or obligating the fees received, and a few districts had not spent or obligated any funds though they had been collecting fees as compensation for wetland losses for at least three years (U.S. General Accounting Office 2001). The study found that three districts used the fees for research and/or education, rather than on-the-ground activities to compensate for wetland loss. In-lieu fee programs in 30% of the districts restored, created, enhanced, or preserved wetland acreage equal to or greater than the wetland acreage lost. The remaining districts either had used the fees to implement wetland activities that did not compensate for the wetland acreage lost, or they did not have any data (U.S. General Accounting Office 2001).

A study by the Environmental Law Institute found that 45% of in-lieu fee programs lacked the data necessary to determine their effectiveness. In-lieu fees replaced more wetland acreage than was lost in 56 programs, while "thirteen in-lieu-fee programs reported replacing fewer acres than had been impacted" (Environmental Law Institute 2002).

These studies paint a rather grim picture of the effectiveness of in-lieu fee programs as compensation for wetland loss. However, both in-lieu fees and mitigation banking can provide a mechanism to compensate for regulated wetland impacts that are so small they currently do not require compensation, because compensation for such small wetland losses was not considered viable or practical (Shabman et al. 1993). In the year 2000 federal guidance on the use of in-lieu fee arrangements for compensatory mitigation was issued, while prior to this there were no federal requirements for in-lieu fee programs (Environmental Law Institute 2002). Further study will be needed to ensure that abuses of in-lieu fee compensation are not occurring.

6.5.8 Summary of Key Points

- The variety of definitions or criteria associated with types of compensatory mitigation has led to confusion in permitting and evaluating projects. For instance, comparing the effectiveness of one type of compensation with another is impossible when it is not clear if a project involved creation, restoration, enhancement, or some combination thereof.

- Restoration has been recommended as the "highest priority" method for compensation. Research in Washington has found that it is the least used, though one of three projects was in compliance and one of two projects was fully successful.

- Creation was used in one-third to one-half of compensation projects. In Washington, 10% of creation projects were in compliance, 60% were at least moderately successful. Studies from other states indicated that creation projects experienced major problems such as a failure to establish vegetation and produce wetland conditions.

- Enhancement was used for compensation in more than one-third of compensation projects. Research in Washington found that less than 13% of enhancement projects were in compliance. There were no fully successful enhancement projects, while 89% were minimally or not successful.

- The low level of success for enhancement projects was attributed to an inability to achieve the proposed vegetative structure/diversity, a minimal gain in functions, or both. This may partially be a factor of time: There will be continued temporal loss of some functions until young sites mature to more complex structural conditions.

- Two studies from Washington indicated that mixed compensation projects had a higher level of compliance than either creation or enhancement, and all mixed projects were moderately successful.

- Preservation can result in permanent protection of existing wetland resources, but compliance was found to be variable. One study found a large area of preserved wetland was actually predominantly upland habitat. However, a study in Washington found that 100% of preservation sites were in compliance.

- Studies of wetland mitigation banking and in-lieu fee programs focused on whether the goal of preventing the net loss of wetlands had been achieved on paper. The results indicated that a net loss of wetland area was occurring. A few banks were overdrawn, and some of the in-lieu fee programs had not used the money collected to implement compensation activities. No studies determined their effectiveness on the ground.

Does size influence the effectiveness of compensatory wetland mitigation projects?

Studies of the effect of wetland size on compensation projects revealed mixed results.

Two studies indicated that larger projects, which probably involved more planning and regulatory oversight, had a higher level of compliance (Brown and Veneman 2001) or success (Allen and Feddema 1996). Allen and Feddema (1996) noted that large projects (greater than 8.6 acres [3.5 ha]) resulted in a net gain of wetland acreage, while the smaller projects resulted in a net loss of wetland acreage. Though Brown and Veneman (2001) indicated larger projects had a higher level of compliance, larger projects were no more successful at replacing the plant communities or wildlife functions that were lost than the smaller compensation wetlands.

Two other studies determined that no statistically significant correlation existed between wetland size and compliance or success (Balzano et al. 2002, Johnson et al. 2002). Raw data from Johnson et al. (2002) implied that compensatory mitigation projects 5 acres (2 ha) or larger were less successful than smaller projects. Balzano et al. (2002) found that larger compensation wetlands tended to be more successful at establishing the required wetland acreage. However, this trend was attributed to one large site (over 40 acres [16 ha]) that established more wetland acreage than was required.

The Committee on Mitigating Wetland Losses determined that wetland size does affect wetland functions (National Research Council 2001). For example, “for water quality purposes, many small wetlands would be more effective than one large wetland covering the same area.” The committee therefore concluded that “replacement area should be proportional to the area required to replace the functions lost” (National Research Council 2001).

6.6 Replacement Ratios

A replacement ratio, or compensation ratio, is an approach used to determine appropriate reparation for permitted wetland losses. Not all regulatory agencies use this approach. For example, the U.S. Army Corps of Engineers, Seattle District considers the needs for compensation on a project-specific basis rather than assigning replacement ratios.

The replacement ratio reflects the acreage of a particular type of compensatory mitigation (creation, restoration, enhancement, or preservation) required to make up for the loss of an acre of wetland (King et al. 1993, McMillan 1998). For example, a permitted loss of one acre may be compensated with two acres of restoration, thus requiring a 2:1 replacement ratio. The rationale for requiring more than 1:1 replacement for wetland impacts is provided in Section 6.6.1.

This section provides the following information:

- The rationale for using replacement ratios
- A summary of the literature regarding what replacement ratios are being required and if they are being achieved
- Some of the methods used to determine appropriate replacement ratios

6.6.1 Rationale for the Use of Replacement Ratios

When compensatory wetland mitigation was first required, the loss of an acre of wetland would simply require an acre of compensation (McMillan 1998). A simple 1:1 replacement ratio generally is no longer considered appropriate (Castelle et al. 1992a, King et al. 1993, National Research Council 2001) for the following reasons:

- **Risk of failure.** It is possible that compensation projects will not perform as proposed (King and Bohlen 1994) and may fail to compensate for wetland losses (Castelle et al. 1992a).
- **Temporal loss.** It may take anywhere from several years to several decades for a compensation project to achieve ecological equivalency (National Research Council 2001) and to develop the proposed/required wetland structures and/or functions (Castelle et al. 1992a).

Because of the risk of failure and temporal loss, "replacement ratios greater than 1:1 are used as a means of equalizing the tradeoff. While the goal is always to replace the lost functions at a 1:1 ratio, it is almost always necessary to increase the replacement acreage in order to accomplish this" (McMillan 1998).

A literature review performed by Castelle et al. (1992a) concluded that:

> *The risks of project failure and the time it takes for a created wetland to represent a fully functioning ecosystem should be factored into replacement ratios which exceed 1:1…*
>
> *Replacement ratios of 2:1 or greater are necessary to compensate for our current rate of failure to achieve permit compliance of basic wetland community structural objectives within attempted mitigation projects, neither of which are accurate measures of functional equivalency.*

An additional consideration is that there are many types of wetlands and various degrees of degradation. As a result, not all wetlands provide the same levels of functions or values. Replacement ratios, therefore, should take into account the type and quality of the wetland and the functions and values that would be lost. For example, the loss of a high-quality forested wetland would require a higher replacement ratio than the loss of a highly degraded wet pasture (Breaux and Serefiddin 1999).

Also, the type of compensation can influence the replacement ratio. Johnson et al. 2002 found that the use of enhancement not only results in a net loss of wetland area but provides a limited increase in wetland functions. Therefore, enhancement typically requires higher replacement ratios than restoration or creation (McMillan 1998).

Higher replacement ratios result in more area for compensatory mitigation, but unfortunately size does not guarantee success or quality. A study conducted by the National Academy of Sciences concluded that attempts to compensate for rare wetland types by requiring high replacement ratios yielded wetlands of a common type at a low ratio. Rather than replicating the rare wetland type, a more common wetland type was substituted. "In effect, the regulatory program may reassemble the landscape with a different habitat mix than the wetlands being lost" (National Research Council 2001).

6.6.2 Replacement Ratios Required and Achieved

Table 6-8 summarizes the overall or average replacement ratios that were required for compensatory wetland mitigation projects. A wide range of replacement ratios was required—from 0.66:1 to 5.9:1 (Kunz et al. 1988, Johnson et al. 2000). These are the extremes. The low end represents projects from the early to mid 1980s, when compensatory mitigation was still a relatively new idea. The higher ratios reflect more recent projects using predominantly enhancement and/or preservation, which typically require higher replacement ratios.

Between these extremes, the remaining studies noted ratios ranging from 1.5:1 to 2.7:1 (Wilson and Mitsch 1996, Morgan and Roberts 1999, Michigan Department of Environmental Quality 2000, Balzano et al. 2002, Johnson et al. 2002, Robb 2002).

Actual replacement ratios that were achieved for the projects studied are also shown in Table 6-8. None of the studies found that the required ratios had been realized. In fact, Balzano et al. (2002) determined that forested compensation wetlands achieved only 1/100th of an acre for every acre lost despite the fact that over 2 acres of forested wetland were required. Achieved ratios ranged from 0.7:1 to 1.9:1 (Wilson and Mitsch 1996, Morgan and Roberts 1999, Balzano et al. 2002, Johnson et al. 2002, Robb 2002).

As mentioned in the previous section, replacement ratios typically require greater than 1:1 replacement to factor in the risk of failure. Table 6-8 demonstrates the utility of this approach since all of the studies indicated that the achieved ratios were smaller than those required. All but one of the studies found the achieved ratios were greater than 1:1, though not by a substantial margin. But two of these studies included enhancement of existing wetlands.

Ratios are a tool to address the temporal loss of wetland functions and the historic failure of replicating wetland acreage and functions. The results indicate an inability of compensation projects to achieve their required replacement ratios. It is assumed that this inability reflects the same problems and shortfalls associated with compensation project success and compliance (see Section 6.4).

Table 6-8. Comparison of replacement ratios that were required and achieved.

Location of Study and Reference No.	No. of Projects Evaluated	Replacement Ratio Required	Replacement Ratio Achieved	Comments
Washington (Johnson et al. 2002)	24	2.2:1[a]	1.87:1 [a]	Enhancement accounted for 65% of the established acreage
Washington (Johnson et al. 2000)	45	5.9:1 [a]	NA	Acreage predominantly preservation and enhancement
Washington (Kunz et al. 1988)	35	0.66:1	NA	Corps and EPA data 1980 to 1986
Michigan (Michigan Department of Environmental Quality 2000)	76	1.82:1 (average)	NA	Required ratios ranged <1:1 to >5:1; study did not include enhancement
Indiana (Robb 2002)	31	2.5:1	1.1:1	Achieved ratios for specific Cowardin classes ranged from 0.48:1 for PFO to 45:1 for POW; study did not include enhancement
Ohio (Wilson and Mitsch 1996)	4 (5)	1.5:1 (1.7:1) [a]	1.4:1 (0.7:1) [a]	Study reviewed 5 projects, results and conclusions focus on 4; parentheses reflect results for all 5
New Jersey (Balzano et al. 2002)	75	1.8:1 (average) 2.04:1 PFO 2.78:1 PSS 1.85:1 PEM 1.07:1 POW	0.78:1 (average) 0.01:1 PFO 0.91:1 PSS 1.29:1 PEM 0.28:1 POW	Sites proposing POW did not achieve the required acreage. However, POW was on sites that did not propose to have open water; thereby resulting in three times more POW acreage than required
Tennessee (Morgan and Roberts 1999)	47	2.7:1	1.9:1	Ratio = 0.88:1when enhancement and preservation are excluded

NA = not available

PFO = palustrine forested; PSS = palustrine scrub-shrub; PEM = palustrine emergent; POW = palustrine open water

[a] Calculated from data provided.

6.6.3 Approaches for Determining Replacement Ratios

King et al. (1993) proposed a framework for calculating replacement ratios, "based on the idea that compensatory mitigation involves trading one form of environmental capital for another and that full compensation requires increases in environmental functions and values from the compensation wetland that are sufficient to make up for the decline in functions and values resulting from the loss of existing wetland." The authors mentioned five parameters to consider when determining an appropriate replacement ratio.

- The pre-existing level of wetland function per acre at the site proposed for wetland compensation. In the case of enhancement, this ensures that an applicant does not get mitigation credit for functions that were already being provided by a pre-existing wetland.
- The maximum level of function anticipated to be provided by the wetland compensation project.
- The number of years after construction that will be required for the wetland compensation project to reach its anticipated or sustainable level of function.
- The number of years between the loss of the original wetland and the completion of construction of the compensation wetland (temporal loss). Mitigation could be done concurrent with impacts, in advance, or delayed after impacts occur.
- The likelihood that the project will not achieve its anticipated level of function.

King et al. (1993) suggested entering the values for each of the five parameters into an analytic model that then calculates an appropriate compensation ratio for the project-specific information provided. King and Bohlen (1994) provided easy to use tables of replacement ratios that would result from a variety of values for the five parameters identified above. Using parameters comparable to King et al. (1993) for determining appropriate compensation, Rheinhardt et al. (1997) described an approach based on function assessment. The authors proposed the following steps.

1. Develop a function assessment method for the specific regional conditions, including identification of reference wetlands.

2. Assess wetlands proposed to be lost, thereby determining the level of each wetland function that will be lost.

3. Assess potential compensatory mitigation sites to evaluate their current level of function and predict future conditions and levels of function that would result from mitigation activities within the timeframe required for regulatory monitoring.

4. Calculate ratios for compensation for each function "by dividing the degree to which a function is reduced through project alteration by the degree to which a function is increased through restoration" (Rheinhardt et al. 1997).

The ratio "varies among functions and is influenced by (1) the magnitude to which any given function occurs at a project site both before and after the site is altered, (2) the magnitude to which any given function occurs at a compensatory mitigation site both before and after restoration is applied, and (3) the rate at which any given function is restored" (Rheinhardt et al. 1997). The goal of this approach is not just to ensure no net loss of wetland functions but also to restore wetland ecosystems (Rheinhardt et al. 1997).

In contrast, Breaux and Serefiddin (1999) argue that "there has not been any single, universally accepted assessment procedure to determine wetland functions and values (Kusler 1997)." As a result they suggest that "the quantitative measure of area provides a degree of certitude that should be taken advantage of" (Breaux and Serefiddin 1999). In other words, assessing or determining the level of functions provided by a wetland can be time-consuming to near impossible, while acreage provides an easy measurement. The authors mention a few conditions that may require greater than 1:1 replacement ratios (for example 2:1 or 3:1):

1. *If it is determined that the area lost includes functions and values of high quality…*

2. *If… the replacement area is outside the watershed, sub-watershed, or county;*

3. *If the replacement area involves a high risk of failure or uncertain outcome,*

4. *If there are high temporal losses…*

5. *If the habitat loss is likely to be substantially greater than the creation of new habitat; or*

6. *If the connection between two wetland sites is severed or a large site is divided* (Breaux and Serefiddin 1999).

Robb (2002) also proposed using an acreage-based system for determining appropriate replacement ratios. However, where the previous studies did not base ratios on the type of wetland, his system focused on developing replacement ratios for each Cowardin class. This approach resulted from a delineation of 31 compensatory mitigation sites in Indiana. Robb (2002) compared the required acreage of each Cowardin class with the acreage that was established. For example, results indicated that 71% of the required acreage of palustrine forested wetlands was not established (a 71% rate of failure). The ratio recommended to overcome this failure was calculated by dividing the required acreage by the acreage actually established. Using these data, the ratio for palustrine forested wetlands should therefore be 3.5 acres of compensation for every acre of wetland lost. The rationale was that for every 3.5 acres constructed that were intended to be palustrine forested wetland, 1 acre would actually become forested wetland. Proposed ratios for other wetland types included:

- 1.8:1 for scrub-shrub
- 7.6:1 for wet meadow
- 1.2:1 for shallow marsh
- 1:1 for open water

Robb (2002) conceded that his study did not consider the quality of the compensation wetlands or whether they replaced the functions lost. The author mentioned that more regulatory follow-up could result in more successful projects and therefore lower replacement ratios.

6.6.4 Summary of Key Points

- Replacement ratios provide a means of taking into account the potential failure and temporal loss of functions as well as the potential change in acreage or functions to be provided by the compensation project.
- Several methods are available to calculate replacement ratios on a case-by-case basis. Examples of some of the criteria used to determine ratios include the functions proposed to be provided at the compensation site, the functions anticipated to be lost at the impact site, size, landscape position, and relative chance of success.
- Required replacement ratios vary from one state to another, based on the type of compensation proposed, and based on project-specific circumstances.
- Studies found that compensation projects did not achieve their required replacement ratios. In some cases this resulted in less than 1:1 acreage replacement.

6.7 Replacement of Wetland Acreage

This section summarizes the results of studies examining whether compensatory wetland mitigation is replacing the acreage of authorized wetland losses. Replacement of wetland acreage is similar to “no net loss,” which refers to a goal for the nation and Washington State to ensure there will be no overall net loss in acreage and function of the remaining wetland resource base (The Conservation Foundation 1988, McMillan 1998). The no-net-loss goal, however, “does not mean that no further wetlands will be lost; rather, that mitigation and non-regulatory restoration will offset wetland losses” (McMillan 1998). Replacement of wetland acreage, on the other hand, focuses on wetland losses and gains associated with compensatory wetland mitigation.

Replacement of wetland acreage provides a measurable and consistent method for evaluating and comparing the effectiveness of compensatory mitigation programs (Kusler 1988). The scientific literature contained two types of information on this topic.

- Studies that evaluated how well permitting programs (e.g., Section 404) achieved replacement of wetland acreage. Most of these studies used information from permit files and databases.
- Studies that evaluated how well compensation projects achieved the replacement of wetland acreage on the ground. These studies were conducted in the field and typically involved the delineation of wetland boundaries.

6.7.1 Programmatic Evaluations of Acreage Replacement

Programmatic evaluations, in contrast to most of the studies mentioned thus far, are not concerned with the effectiveness of individual compensatory mitigation projects. Instead, programmatic evaluations focus on whether a permitting agency or permit program is requiring sufficient wetland acreage compensation to replace the authorized wetland losses occurring over a specified time.

In a programmatic evaluation, wetland acreage replacement is determined by comparing the acreage of wetlands lost, or adversely altered, with the acreage of wetlands required for compensatory mitigation in a specific geographic area. These evaluations typically rely on information from permit files and databases, rather than verification of on-the-ground, as-built conditions.

Five studies examined the effectiveness of wetland permitting and compensatory mitigation programs (Table 6-9). The earliest study reviewed Section 404 permit data from Washington, 1980 to 1986, and Oregon, 1977 to 1987, "to describe how permit decisions affect the wetland resource" (Kentula et al. 1992). Results indicated that in Washington 39 acres (16 ha) of wetland were not replaced, while in Oregon 79 acres (32 ha) of wetland were not replaced. The authors also observed, "In Washington, approximately 3 percent of the permits issued required compensatory mitigation" (Kentula et al. 1992).

The results of this study should be considered within the context of the Seattle District Corps of Engineers regulatory program in the early 1980s. The authors of Volume 1 observed that in the early 1980s compensatory mitigation, when it was required, was only required for projects that triggered an individual permit. The threshold for wetland fill under a Nationwide Permit 26 (a general permit for headwaters and isolated waters discharges) was 10 acres (4 ha), therefore an individual permit was only required for projects with greater than 10 acres of wetland fill. Fill of 10 acres or less in isolated wetlands was permitted outright. It is therefore possible to conclude that the 40 acres of wetland identified by Kentula et al. (1992) as "not replaced" very likely represents but a fraction of the total acreage of permitted wetland losses that were not compensated for at that time.

A study of Section 404 permitting from southern California noted that 8 acres (3 ha) of wetland were not replaced (Allen and Feddema 1996). The study also determined that "freshwater wetlands are experiencing a disproportionately greater loss of area and that riparian woodland wetlands are most often used in mitigation efforts. The net result of these accumulated actions is an overall substitution of wetland types throughout the region" (Allen and Feddema 1996).

Two of the remaining studies generally found that permitting programs required a net gain from compensatory mitigation (Table 6-9). Gains in acreage ranged from about 47 acres (19 ha) (Torok et al. 1996) to nearly 197 acres (80 ha) (Holland and Kentula 1992). However, the study of the effectiveness of the New Jersey Freshwater Wetlands Protection Act (Torok et al. 1996) mentioned compensatory mitigation acreage only for individual permits. It was not clear from the article if any of the 3,003 general permits, resulting in over 600 acres (243 ha) of wetland loss, required any compensatory mitigation. Furthermore, Holland and Kentula (1992), in their evaluation of Section 404 permitting in California, noted that data on acreage of impacts and compensation were lacking in about 40% of the permit files.

The fifth study focused on the Norfolk Corps District (Jones and Boyd 2000). The authors indicated that new wetland acreage produced by creation or restoration did not fully replace the permitted wetland losses, thereby resulting in a loss of about 260 acres (105 ha) (Jones and Boyd 2000). However, preservation, mitigation bank credits, and substantial in-lieu fee contributions provided additional compensation. If acreages from all types of compensatory mitigation are included, the authors assumed there was a gain of at least 1,500 acres (607 ha). Despite the fact that only 24% of the permits required compensation, the authors concluded that replacement of wetland acreage was achieved, at least on paper (Jones and Boyd 2000).

The results (Table 6-9) indicate that since the early 1980s, permitting programs have required an increasing amount of acreage to compensate for wetland losses. It can be inferred that permits from the mid-1980s did not require the replacement of acreage for wetland losses, whereas permits from the mid- to late 1990s appear to have required replacement of wetland acreage.

Table 6-9. Permitted wetland loss compared to required wetland compensation.

Location of Study	No. of Permits	Wetland Area Lost	Area of Compensation Required	Comments
Washington (Kentula et al. 1992)	35	152 acres (61.4 ha)	112 acres (45.5 ha) created	Section 404 permits 1980-1986
Oregon (Kentula et al. 1992)	58	183 acres (73.9 ha)	103 acres (41.8 ha) created	Section 404 permits 1977-1987
California (Holland and Kentula 1992)	324	2,907 acres (1,176.3) ha	3,103 acres (1,255.9 ha)	Section 404 permits 1971-1987; data on acreages was often lacking

Location of Study	No. of Permits	Wetland Area Lost	Area of Compensation Required	Comments
California/ southern (Allen and Feddema 1996)	75	199 acres (80.5 ha)	191 acres (77.3 ha) completed	Section 404 permits 1987-1989; permits required 276 acres (111.6 ha) of compensatory mitigation
Norfolk Corps District (Jones and Boyd 2000)	1692	863.8 acres (349.6 ha)	538.6 acres created (218.0 ha) 65.5 acres restored (26.5 ha) 1,537.2 acres preserved (622.1 ha) 200.8 bank credits $2,574,966 in lieu fee	Section 404 permits 1996-1998
New Jersey (Torok et al. 1996)	3003 (107)	602 acres (243.8 ha) *164 acres (66.5 ha)*	NA *171 acres (69.2 ha) created;* *41 acres (16.5 ha) restored*	New Jersey Freshwater Wetlands Protection Act permits 1988-1993. *Numbers in italics are individual permits; all other numbers are state general permits.*

6.7.2 Project-Specific Evaluations of Acreage Replacement

Studies that examined the effectiveness of compensation projects often assessed whether the projects achieved replacement of wetland acreage. The assessment generally involved determining how much wetland acreage the compensation projects provided. The wetland compensation acreage produced on the ground was then compared to the acreage of wetland loss associated with those projects. If the compensation acreage was less than the wetland acreage lost, a net loss of wetland occurred. Seven studies analyzed compensatory wetland mitigation project data to determine whether replacement of wetland acreage was achieved.

Four studies either focused on creation or restoration, or they did not mention the type of compensation. The studies noted that the acreage of wetland compensation was less than the acreage of wetland loss by as much as 34%, thereby resulting in a net loss of up to 8 acres (3 ha) (Gwin and Kentula 1990, Allen and Feddema 1996, Wilson and Mitsch 1996). However, a study conducted for the South Florida Water Management District found that creation and restoration activities resulted in 106% of the wetland acreage lost—a net gain of almost 65 acres (26 ha) of wetlands (Erwin 1991).

One issue that emerges when considering replacement of wetland acreage is the use of enhancement and preservation as wetland compensation. Three studies noted that enhanced or preserved wetlands accounted for 45 to 65% of the acreage of compensation (Shaich and Franklin 1995, Morgan and Roberts 1999, Johnson et al. 2002). In Washington nearly two-thirds of the established acreage of compensation involved enhancing existing wetlands, while creation and restoration of wetland area replaced only 65% of the permitted wetland losses (Johnson et al. 2002).

Some authors discounted the acreage provided by enhancement and preservation. Enhancement and preservation are often not included in determining net loss or gain because neither type of compensatory mitigation produces any new wetland acreage (Breaux and Serefiddin 1999). When acreage provided by enhancement and preservation are disregarded, three studies found wetland losses of 22, 11, and 24 acres (9, 4, and 10 ha) respectively (Shaich and Franklin 1995, Morgan and Roberts 1999, Johnson et al. 2002). This equaled 58, 12, and 41% of the authorized wetland losses, respectively (Shaich and Franklin 1995, Morgan and Roberts 1999, Johnson et al. 2002).

6.7.3 Summary of Key Points

- Programmatic evaluations have documented an increase in the acreages of wetland compensation required since the early 1980s. However, the acreage of wetland replacement may include preservation, enhancement, or both.
- Project-specific data revealed that compensation wetlands did not replace the acreage of wetlands that were lost. Even larger losses occurred if the acreages of enhancement and preservation were discounted.

6.8 Functions and Characteristics Provided by Created, Restored, or Enhanced Wetlands

This section describes the functions and characteristics provided by wetlands created, restored, or enhanced for compensatory mitigation and non-regulatory projects.

- The capacity of created and restored wetlands to provide wildlife habitat for invertebrates, amphibians, and birds. Wildlife habitat was evaluated through direct observations or evidence of wildlife use, the presence of structural indicators, or comparison to reference wetlands.
- The ability of created, restored, or enhanced wetlands to develop plant communities and vegetative characteristics. Studies involved comparisons with reference wetlands and investigations of factors affecting vegetation.
- The importance of soil conditions, particularly as they relate to establishing vegetation and improving water quality. Soil properties of created and restored wetlands were compared with reference wetlands.
- The ability of created and restored wetlands to provide water quality functions.
- The importance of water regime and how the creation and enhancement of compensation wetlands can result in atypical water regimes.

The scientific literature indicated that the ability of compensatory wetland mitigation projects to perform wetland functions is not noticeably different from that of non-regulatory restoration or creation projects. Newly implemented wetland sites face similar challenges and develop in similar ways regardless of whether they were legally required or voluntarily initiated.

Refer to Chapter 2 of this document for a discussion of the functions that wetlands provide.

In Section 6.8, use of the terms "**significant**" and "**significantly**" implies statistical significance that was determined by the authors of the specific study being discussed.

6.8.1 Wildlife Habitat

Most articles focused on the ability of a created or restored wetland to provide habitat for one specific guild or group of animals, such as invertebrates, amphibians, or birds. Information on other habitat functions provided by created or restored wetlands was lacking.

6.8.1.1 Invertebrates

Several studies have compared the invertebrate communities of created or restored wetlands with those of reference wetlands. Most of these determined that reference wetlands were more diverse, had greater taxon richness, or had higher density of species than created or restored sites (Brown et al. 1997, McIntosh et al. 1999, Fairchild et al. 2000, Dodson and Lillie 2001). One study, however, found "no convincing differences" in fly (dipteran) densities between created and reference wetlands (Streever et al. 1996). None of these studies were conducted in the Pacific Northwest. However, the results should be broadly applicable to wetlands anywhere.

The age of the wetland, or the amount of time elapsed since restoration occurred, was an important factor influencing invertebrate taxon richness, abundance, and/or diversity (Brown et al. 1997, Fairchild et al. 2000, Dodson and Lillie 2001). For example, "insects with aerial dispersal capability rapidly colonized the restored habitats, but some less mobile forms (non-insects and some hemipterans [true bugs]) either colonized more slowly or not at all" (Brown et al. 1997). Dodson and Lillie (2001) determined that a newly restored site would require 6.4 years for the zooplankton taxon richness to resemble that of a minimally disturbed reference wetland.

The growth and development of vegetation also appears to affect invertebrate communities (Chovanec 1994, Brown et al. 1997, Chovanec and Raab 1997, McIntosh et al. 1999, Fairchild et al. 2000). For example, certain predatory groups of beetles were early colonists at young sites with limited development of vegetation, while herbivorous beetle groups occurred at older sites after specific types of vegetation had developed (Fairchild et al. 2000). McIntosh et al. (1999) concluded, "wetlands at different successional stages may contain very distinct aquatic macroinvertebrate assemblages which may be important to the food web and other functional processes of wetlands."

6.8.1.2 Amphibians

The amphibian habitat present in created or restored wetlands has been compared with that of reference wetlands in several studies. On the east slope of the Cascade Range in the Teanaway and lower Swauk River drainages of Kittitas County, Quinn et al. (2001) found no difference in species richness of amphibians between created and reference wetlands, "although sample sizes may have been too small for differential species-use patterns to emerge." Other authors determined that created and restored wetlands differed from reference wetlands in terms of amphibian community structure, species richness, or stomach content (Bursey 1998, Lehtinen and Galatowitsch 2001, Pechmann et al. 2001).

Though created or restored wetlands provide habitat for some amphibian species, conditions within the wetland and conditions outside the wetland may limit productivity, dispersal, colonization, or all three. Conditions within a wetland that appear to affect amphibian communities include hydroperiod, substrate, presence of emergent vegetation, presence of fish, and the availability of an invertebrate prey source (Bursey 1998, Baker and Halliday 1999, Monellow and Wright 1999, Pechmann et al. 2001).

Conditions outside of a restored or created wetland that affect amphibian communities include distance to other wetlands, connectivity between habitats, and the land use of the surrounding terrestrial habitats (Baker and Halliday 1999, Monellow and Wright 1999, Lehtinen and Galatowitsch 2001, Pechmann et al. 2001). For example, Baker and Halliday (1999) observed that two species of amphibians dispersed to new ponds only if they were within 1,312 feet (400 m) of an existing pond, while two other species colonized new ponds up to 3,117 feet (950 m) from an existing pond.

Monellow and Wright (1999) concluded, "The interconnectiveness of amphibian habitat is an essential element in sustaining amphibian populations because it allows amphibians to overcome large population fluctuations and recolonize areas where populations have been extirpated."

Lehtinen and Galatowitsch (2001) found that the wetlands restored in urban areas had the lowest amphibian species richness. However, authors of a study of wetlands created in a recreational area in an intensively used urban site near Vienna, Austria observed all seven of the amphibian species known to occur in the area. As many as six species were breeding (Chovanec 1994).

6.8.1.3 Birds/Waterfowl

All of the studies that examined the ability of created or restored wetlands to provide habitat for birds focused on non-regulatory projects. Therefore this section does not contain information on the ability of compensatory wetland mitigation projects to provide habitat for birds. However, the information is still relevant based on the similarity of results among compensatory and non-regulatory projects for the other studies of functions. None of the studies cited below were conducted in the Pacific Northwest.

Studies comparing bird use of created or restored wetlands and reference wetlands demonstrated variable results, perhaps indicating that site-specific conditions influence bird use. For example, two studies found no difference in bird abundance between restored and reference wetlands (Brown and Smith 1998, Ratti et al. 2001), while two other studies determined that reference wetlands had greater bird species richness and abundance (Delphey and Dinsmore 1993, Dobkin et al. 1998). Brown and Smith (1998) found no difference in bird abundance or the number of bird species observed. However, they did determine that the bird communities differed by a statistically significant margin and that density was greater at reference wetlands (Brown and Smith 1998). Regardless of the findings for bird populations in general, two studies noted that ducks had similar or greater abundance, species richness, or density at created and restored wetlands (Delphey and Dinsmore 1993, Ratti et al. 2001).

In the literature, the main factors that appeared to affect wetland use by bird populations were:

- The percent cover of emergent vegetation (Belanger and Couture 1988, Hemesath and Dinsmore 1993, VanRees-Siewert and Dinsmore 1996)
- The density and abundance of invertebrates (Belanger and Couture 1988, Cooper and Anderson 1996)

Though the age of the wetland did not directly affect overall bird populations at created and restored wetlands, VanRees-Siewert and Dinsmore (1996) noted that the richness of breeding bird species was significantly greater at older restoration sites. The composition of the bird community changed with age. Both of these effects were associated with an increase in the emergent vegetation in older wetlands.

6.8.2 Plants

6.8.2.1 Comparisons with Reference Wetlands

This section discusses studies that compared the vegetation of created and restored wetlands to that of reference wetlands. The studies examined a variety of parameters in a number of states and found variable results. Only one study determined that there was no difference in vegetation between created/restored and reference wetlands (Brown 1991). Two studies were conducted in the Pacific Northwest.

In the metropolitan area of Portland, Oregon, reference wetlands differed significantly from mitigation wetlands in terms of floristic composition. Mitigation wetlands had higher overall plant species richness, higher average percentage of native species, and significantly higher average occurrence of introduced and invasive/introduced species than reference wetlands (Magee et al. 1999).

Another study was conducted in the northwestern Great Basin on land that had previously been grazed by cattle. The study found that "sedge cover, forb cover, and foliage height diversity of herbs were greater" on reference plots, in which livestock had been excluded for more than 30 years. "[B]are ground, litter cover, shrub cover, and shrub foliage height diversity were greater" on restored plots, in which livestock grazing pressure had been removed prior to commencement of the study (Dobkin et al. 1998). During the four-year study period, restored plots experienced an increase in grass, forb, rush, and cryptogamic cover, but sedge cover did not change. The authors concluded, "the lack of change in sedge and shrub cover on open [restored] plots suggests that restoration to a sedge-dominated meadow will not happen quickly" (Dobkin et al. 1998).

Restored prairie pothole wetlands were found to lack low prairie and wet meadow zones that reference wetlands possessed. Restored wetlands had significantly higher richness of submersed aquatics and greater coverage by mudflat and open water (Delphey and Dinsmore 1993, Galatowitsch and van der Valk 1995, Galatowitsch and van der Valk 1996). The researchers concluded that restored wetlands are not likely to develop the sedge meadow and wet prairie zones present in reference wetlands (Galatowitsch and van der Valk 1995, VanRees-Siewert and Dinsmore 1996).

Other authors determined that reference wetlands exhibited greater percent cover by wetland species. However, created wetlands had species richness that was equal to or greater than reference wetlands (Moore et al. 1999). Restored wetlands had significantly lower wetland index values (indicating that wetland species were providing more of the total vegetative cover) than reference sites (Brown 1999).

One could hypothesize that created and restored wetlands have greater vegetation species richness due to the level of disturbance associated with creation and restoration and the broad range of niches created on a new site. For example, a newly created or restored site is like a *tabula rasa* (a blank slate) upon which species will be planted (installed or seeded), species from the previous habitat on the site will re-emerge, and species adapted to disturbance will colonize.

6.8.2.2 Cowardin Classes Provided by Compensatory Mitigation Wetlands

Cowardin class refers to a method used to categorize wetlands based on the dominant type of vegetation (Cowardin et al. 1979), as well as other factors. The main Cowardin classes used to categorize freshwater wetlands are:

- Emergent
- Scrub-shrub
- Forested
- Aquatic bed
- Open water (though not technically a Cowardin class, open water is often used to map and describe unvegetated areas of inundation)

Several studies evaluated compensatory wetland mitigation sites to determine which Cowardin classes were being established. Nearly all of these studies found that compensatory mitigation resulted in more acreage of open water/aquatic bed/deep marsh than was originally lost or required (Kentula et al. 1992, Shaich and Franklin 1995, Bishel-Machung et al. 1996, Magee et al. 1999, Cole and Brooks 2000, Michigan Department of Environmental Quality 2000, Balzano et al. 2002, Johnson et al. 2002, Robb 2002).

For example, in Washington State over 16 acres (6 ha) of open water/aquatic bed wetlands were gained (Johnson et al. 2002). In the Portland metropolitan area of Oregon, 29 acres (12 ha) of open water were gained (Shaich and Franklin 1995), and Indiana gained over 3 acres (1 ha) of open water/deep marsh/aquatic bed (Robb 2002). Compensatory wetland mitigation projects in New Jersey generated 50 acres (20 ha) more open water than was required (Balzano et al. 2002).

Results for other Cowardin classes were more variable. For example, four studies noted either a loss of forested wetland area (4 to 8 acres [2 to 3 ha]) or an inability to establish this wetland class (Shaich and Franklin 1995, Bishel-Machung et al. 1996, Brown and Veneman 2001, Balzano et al. 2002, Robb 2002). On the other hand, a study from Washington State observed a net gain of over 12 acres (5 ha) in forested/scrub-shrub wetlands (Johnson et al. 2002).

Additional variability occurred in the balance of emergent wetlands. Two studies from the Pacific Northwest noted a loss of 35 to 51 acres (14 to 21 ha) for emergent wetlands due to their conversion to other Cowardin classes (Shaich and Franklin 1995, Johnson et al. 2002). Studies from other states, meanwhile, found that emergent wetlands were established more successfully than other wetland classes (Bishel-Machung et al. 1996, Brown and Veneman 2001, Balzano et al. 2002). Though the studies did not mention whether the emergent wetlands were dominated by native vegetation, Brown and Veneman (2001) noted "plant communities in replicated wetlands differed significantly from those in wetlands they were designed to replace" in terms of the number and percent cover of species in general and the number and percent cover of wetland species.

Compensatory mitigation may often result in a different wetland type compared to what was lost (Shaich and Franklin 1995, Balzano et al. 2002, Johnson et al. 2002, Robb 2002). For example, if an open-water pond was provided as compensation for an authorized impact to a wetland pasture, a change in wetland type occurred. If the compensatory mitigation was enhancement and involved constructing an open water pond in another wetland pasture, a second change in wetland type occurred.

The studies examining changes in Cowardin classes at compensation wetlands found a net increase in open water/aquatic bed habitats (Shaich and Franklin 1995, Balzano et al. 2002, Johnson et al. 2002, Robb 2002). Though the reasons for this change are not clear for all studies, several studies indicated that open water/aquatic bed resulted from an inability to establish the proposed Cowardin class (Balzano et al. 2002, Robb 2002). One could assume that another reason may be that open water is relatively easy to establish given adequate hydrologic conditions. Furthermore, the authors of Volume 1 have observed situations in which the wetland mitigation design was intended to maximize a limited space by providing a variety of habitat niches, and open water is often considered a key habitat niche for waterfowl. Therefore, it is possible to conclude that regulatory decisions may have been biased toward the construction of more open water/aquatic bed/emergent wetland complexes in order to achieve an enhancement of functions in a limited space.

Studies from Washington and Oregon reported a net loss of emergent wetlands (Shaich and Franklin 1995, Johnson et al. 2002). However, many wetlands in the Puget Lowlands of Washington and the Willamette Valley of Oregon that are classified as emergent are wet pastures dominated by non-native grasses. Johnson et al. (2002) noted that 90% of the emergent acreage lost or converted was pasture dominated by non-native species. It can be assumed that much of the current area of emergent pasture may historically have been forested wetland. Therefore, one can conclude that converting pastures into other wetland types with a greater diversity of hydroperiod and more structural complexity, such as forested wetlands, may represent an opportunity for a net increase in wetland functions over time, compared with leaving the wet pastures unchanged.

6.8.2.3 Factors Affecting Plants

Several major factors influencing wetland vegetation have emerged from the literature:

- Soil and soil disturbance
- Age of the wetland
- Competition and non-native vegetation
- Seed or plant source
- Human manipulation

The studies summarized in this section looked at different parameters in different types of wetlands across the country; therefore, the results are highly variable.

Soil and Soil Disturbance

Five studies indicated that soil conditions at the created or restored wetlands influenced vegetation composition (Brown 1991, Ashworth 1997, Brown and Bedford 1997, Stauffer and Brooks 1997, Brown 1999). Three of these studies discussed the positive effects of adding salvaged or donor hydric soil to created or restored wetlands. Benefits included increased species richness (Brown 1991, Stauffer and Brooks 1997) and significantly higher number and percent cover of wetland species (Brown and Bedford 1997). Stauffer and Brooks (1997) concluded that more organic matter in the hydric soil improved the retention of moisture and nutrients, thereby helping to increase plant cover, density, and species richness. Another study, involving dike removal to restore a site, observed that disturbance of the soil resulted in vegetation dominated by cattails (Brown 1999).

Age of the Wetland

The effect of age on the vegetation of created and restored wetlands was noted in various studies (Reinartz and Warne 1993, Magee et al. 1999, Moore et al. 1999). Created and restored wetlands less than three years old differed, in terms of floristic composition, from sites three years and older (Reinartz and Warne 1993, Magee et al. 1999). Older sites had higher mean total plant cover and mean cover of native wetland species (Reinartz and Warne 1993). Moore et al. (1999) found that age, in addition to sedimentation, resulted in:

- A decrease in open water and water depth
- An increase in emergent and woody cover
- An increase in the number of plant species
- An increase in wetland vegetation species richness

In western Washington, Celedonia (2002) investigated the age at which canopy convergence occurs. The study found that "aerial [woody] cover increases with age until year 8 and remains constant into years 10-11." The author noted, "80% cover is generally achieved by year 8, and perhaps as early as year 7." The study found that the most abundant species in terms of frequency and cover were red alder (*Alnus rubra*), willows (*Salix spp*.), black cottonwood (*Populus balsamifera*) and red osier dogwood (*Cornus sericea*). In addition, Celedonia (2002) found that native woody cover was strongly correlated with the density of stems greater than 6.5 feet (2 m) tall, such that percent cover increased as stem density increased up to about 2,100 stems per acre. Sites with densities higher than 2,100 stems per acre generally had greater than 90% woody cover (Celedonia 2002).

Competition and Non-Native Vegetation

The effect of competition on vegetation has been examined in several studies. The studies focused on specific species or treatments used to manage vegetation, factors that affect competition with non-native species, and the presence and extent of non-native species on compensatory wetland mitigation sites.

A few of the studies were conducted outside of the Pacific Northwest, and may have limited applicability to Washington State. For example, in the southeastern United States McLeod et al. (2001) determined that an existing willow canopy did not detrimentally affect the survival of three under-planted tree species. In the Midwest, Budelsky and Galatowitsch (2000) experimented with hairy sedge (*Carex lacustris*). The authors concluded, "*C. lacustris* can produce dense stands under a primarily annual weed community within two to three growing seasons, but that reed canary grass (*Phalaris arundinacea*) can preclude successful establishment of *C. lacustris*" (Budelsky and Galatowitsch 2000).

In the western Washington, Celedonia (2002) found that reed canary grass (*P. arundinacea*) can exist at relatively high densities (as much as 40% aerial cover) under abundant canopy cover (>95%). This study was not able to determine: 1) whether reed canary grass was actually spreading through the understory, or whether it was a remnant, and woody species were establishing ‘over’ it; or 2) the extent to which reed canary grass inhibits establishment of desirable plant species during the re-initiation of the understory (Celedonia 2002).

Research has identified two factors that affect competition with non-native species.

- **Shrub density.** Celedonia (2002) observed, “greater shrub layer densities were associated with less reed canarygrass.” The author suggests that an initial planting of a very dense shrub layer (e.g., more than 3,000 stems per acre) may help to preclude domination of reed canarygrass (*Phalaris arundinacea*).
- **Land use.** Magee et al. (1999) found that “the number of introduced and invasive/introduced species per site increases significantly with more intensive land use.”

A few studies investigated how many compensation projects experienced problems with invasive species or how many non-native species occurred on sites. In Washington State, Johnson et al. (2002) noted that 61% of compensatory mitigation sites had at least 25% of the site dominated by non-native species. Celedonia (2002) found that nearly half of the sites visited in Washington had greater than 10% cover of reed canarygrass. In a study conducted by the Michigan Department of Environmental Quality (2000), “8% of mitigation sites were found to have a problem with invasive species” (defined as constituting 10% or more of the vegetation community).

In the Portland metropolitan area of Oregon, a study of vegetation at compensatory mitigation wetlands observed that non-natives composed more than half of the species present and “nine of the 14 most common taxa were invasive introduced species” (Magee et al. 1999).

Seed or Plant Source

The seed or plant source has been identified as important for restored wetlands (Reinartz and Warne 1993, Galatowitsch and van der Valk 1995). Restoration wetlands seeded with native wetland species had higher diversity and richness and less cover by cattails than the unseeded wetlands (Reinartz and Warne 1993). Emergent perennial species rapidly recolonized restoration wetlands possessing a viable refugium of wetland plant species (e.g., present in existing ditches) that spread through vegetative rooting (Galatowitsch and van der Valk 1995). The importance of proximity to a seed source was mentioned by Reinartz and Warne (1993) but discounted by Galatowitsch and van der Valk (1995).

Kellogg and Bridgham (2002), however, found that low density planting “offered no clear advantages over hydrologic restoration.” Though seeding of a cover crop appeared to limit the establishment of aggressive species such as *Phalaris arundinacea*, it also appeared to limit establishment of wet prairie and sedge meadow species (Kellogg and Bridgham 2002).

Human Manipulation

A study conducted in the Willamette Valley of Oregon examined the response of wetland vegetation to three techniques for the restoration of wet prairie: burning, hand removal, and mowing (Clark and Wilson 2001). Results indicated that:

- **Burning** significantly reduced the survival and percent cover of woody species and non-native forbs (e.g., common St. John's-wort [*Hypericum perforatum*]), increased flowering of slender rush (*Juncus tenuis*), and increased cover of native forbs (e.g., Spanish-clover [*Lotus purshiana*] and marsh speedwell [*Veronica scutellata*]), but decreased flowering of tufted hairgrass (*Deschampsia cespitosa*), the dominant wetland prairie grass.

- **Hand removal** significantly reduced cover by woody species and non-native forbs, increased cover of native forbs, but increased flowering of non-native grasses (e.g., velvet grass [*Holcus lanatus*] and sweet vernal grass [*Anthoxanthum odoratum*]).

- **Mowing** had no effect on cover of woody species, but it increased the flowering of non-native grasses and significantly increased flowering of slender rush.

The authors concluded that though "no treatment was clearly superior in fulfilling the restoration objectives" mowing with removal of cut material was specifically not recommended (Clark and Wilson 2001).

6.8.3 Soil Characteristics

Soils are a critical component of wetlands. Soil characteristics can influence the growth and development of vegetation as well as the ability of wetlands to perform certain water quality functions. Researchers have investigated several factors related to wetland soil characteristics at compensatory wetland mitigation sites, including:

- Organic matter content
- Bulk density (compaction)
- Particle size
- Nitrogen content

Several authors used the approach of comparing soil conditions of created wetlands with reference wetlands. In these studies, the reference wetlands were either of the same wetland types as the mitigation wetlands, or they were adjacent to the mitigation wetlands. Only one study compared treatment plots to control plots at created wetlands. None of the articles on soil characteristics involved non-regulatory projects. Only one was conducted within the Pacific Northwest.

Results consistently indicated that the soil of created wetlands had a lower content of organic matter than reference wetlands (Brown 1991, Bishel-Machung et al. 1996, Streever et al. 1996, Shaffer and Ernst 1999, Whittecar and Daniels 1999, Stolt et al. 2000). Bishel-Machung et al. (1996) found that created wetlands had less organic matter than reference wetlands regardless of the Cowardin class or hydrogeomorphic class.

In the Portland metropolitan area, Shaffer and Ernst (1999) observed that both reference and mitigation wetlands with a high extent and duration of standing water had a lower concentration of soil organic matter. However, the authors also observed a consistent pattern of lower concentrations of organic matter in the soil of mitigation wetlands compared to reference wetlands within the same soil series, texture classes, and associations. Since many of the mitigation wetlands in this study involved construction of a pond in an existing wetland, the authors hypothesized that organic matter in mitigation wetlands is being lost due to the excavation of upper soil layers during project installation (Shafer and Ernst 1999).

In studies examining created wetlands from one to 11 years old and one to eight years old, the age of the created wetlands did not have an effect on organic matter content of the soil (Shaffer and Ernst 1999, Bishel-Machung et al. 1996). Concentrations of organic matter were relatively uniform between surface and subsurface samples. This indicated that accumulation of organic matter was either not occurring or was occurring so slowly it was not detectable (Bishel-Machung et al. 1996, Shaffer and Ernst 1999).

Stauffer and Brooks (1997) examined the effect of adding organic soil amendments to created wetlands. The authors found that plots treated with “salvaged marsh surface” (hydric topsoil) and leaf litter compost contained more organic matter than untreated, control plots. After two growing seasons, soil organic matter remained higher in plots treated with organic soil amendments.

Studies looking at particle size, bulk density, and nitrogen content found that soils in created wetlands had more sand, higher bulk densities (more compacted), and a lower nitrogen content than reference wetlands (Bishel-Machung et al. 1996, Whittecar and Daniels 1999, Stolt et al. 2000). In combination with low organic content, the soil characteristics of created wetlands may hinder plant establishment and growth (Whittecar and Daniels 1999, Stolt et al. 2000), denitrification and pollutant trapping (Stolt et al. 2000), and redox conditions (Bishel-Machung et al. 1996), thereby influencing microbial activity (Whittecar and Daniels 1999).

In contrast, Gilliam et al. (1999) found that redox levels and nitrogen content (in the form of ammonia) at an eight-month-old created wetland were comparable to a reference wetland after the created wetland was inundated. However, pH, phosphorus, manganese, magnesium, and zinc did not change noticeably at the created site. The authors concluded that eight months was “an insufficient period of time for a complete change toward hydromorphic soils.”

6.8.4 Water Quality

Most of the water quality studies investigated the ability of created or restored wetlands to retain sediment, phosphorus, nitrogen, or some combination. One study compared water quality attributes at created and reference wetlands (Streever et al. 1996). None of the studies were conducted in the Pacific Northwest.

6.8.4.1 Comparison of Water Quality at Created and Reference Wetlands

Streever et al. (1996) determined that created wetlands had higher pH and conductivity than reference wetlands. The authors hypothesized that the amount of organic matter in the soil is related to pH and conductivity: "because decomposition of organic material releases CO2, lower pH values would be expected in natural systems with well-developed organic soils. A well-developed organic substrate may isolate surface water from underlying sand and rock, leading to decreased dissolution of minerals and lower conductivity." (See the previous discussion of soil characteristics in Section 6.8.3.)

6.8.4.2 Sediment Removal

Findings related to retention of sediment by created wetlands include the following:

- Wetlands created adjacent to roads were effective at retaining sediment, such that inflow culverts were clogged by accumulated sediment at a couple of sites (Moore et al. 1999).

- Mitsch (1992) found that a created wetland retained 90% of sediments, while a reference wetland retained 3%. The actual amount of sediment retained depends upon the loading rate.

- Fennessey et al. (1994) investigated the location within a created wetland where sediment was retained. Rates of sediment deposition, in general, were highest near the inflow and decreased as distance from the inflow increased, "except when outflow ceased, in which case the maximum sedimentation often occurred near the outfall." Open water areas also had higher sediment deposition than vegetated areas, which restricted flow. The authors observed that vegetation seems to present a barrier to water and sediment flow and, therefore, the study "did not illustrate the conventional belief that the presence of vegetation enhances sedimentation." The authors concluded, "deeper open water areas are more conducive to sediment accumulation than are shallower open water areas that are more easily subjected to wind-driven and biological sediment disturbances and subsequent re-suspension."

6.8.4.3 Nutrient Removal

In several studies, phosphorus retention at created or restored wetlands ranged from 16 to 96% (Mitsch 1992, Mitsch et al. 1995, Niswander and Mitsch 1995, White et al. 2000). In all but one of these studies, created/restored wetlands retained at least 53% of phosphorus (Mitsch 1992, Mitsch et al. 1995, White et al. 2000). The percent of retention varied depending on:

- Whether the wetland experienced high or low flows (Mitsch 1992, Mitsch et al. 1995)
- The configuration of the outflow
- The amount of time water was retained in the wetland (Niswander and Mitsch 1995)

White et al. (2000) mentioned that a restored wetland's capacity for phosphorus retention is limited. Sediments near the wetland inflow had a limited ability for additional uptake of phosphorus. However, approximately 66% of the marsh sediments still had a high capacity for uptake. The authors concluded, "future treatment efficacy may decrease if the remaining sediments become saturated. Continued high P [phosphorus] loading to the marsh may lead to eutrophication problems and downstream P export from the wetland."

Romero et al. (1999) found that total nitrogen retention was 30 to 91% at four restored wetlands. The authors attributed this to the high retention of dissolved inorganic nitrogen, while the retention efficiencies for particulate and dissolved organic nitrogen were much lower. The authors observed no significant difference between nitrogen retention and the age of the restored wetland.

Woltemade (2000) examined the factors that affect the ability of a created or restored wetland to retain nutrients. The most critical design elements for wetlands constructed to treat agricultural runoff were determined to be the retention time (amount of time that water is retained in the wetland) and the wetland-to-watershed ratio (size of the wetland compared to the size of its contributing basin):

> *If nutrient and sediment concentrations are to be reduced to acceptable levels on a landscape scale, drainage water must be retained for at least one to two weeks within wetlands before being discharged into streams. Monitoring of restored wetlands indicates that the longer the retention time, the greater the water quality benefits. . . Ultimately, the appropriate size of a restored wetland will depend on the contaminant of greatest local concern that requires the longest retention time for its degradation, and on the percent reduction of this contaminant that is required seasonally, annually, or interannually (van der Valk and Jolly 1992).* (Woltemade 2000).

6.8.5 Water Quantity

No studies were found that discussed the ability of created or restored wetlands to perform water quantity functions, such as decreasing downstream erosion or reducing peak flows, or that mentioned factors influencing a wetland's ability to perform water quantity functions.

Two studies compared the water regime of compensatory mitigation wetlands with reference wetlands. Both found that the compensatory wetlands had more standing water for a longer period (Shaffer et al. 1999, Cole and Brooks 2000).

6.8.5.1 Using Hydrogeomorphic (HGM) Classification to Study Water Regime at Mitigation Sites

Differences in the water regime between existing wetlands and mitigation wetlands have been examined by several researchers in the Pacific Northwest and elsewhere. The researchers used the hydrogeomorphic (HGM) classification to compare the water regimes of existing wetlands with those of mitigation wetlands. As described in Chapter 2, the HGM classification is based on the position of the wetland in the landscape (geomorphic setting), the wetland's water source, and the flow and fluctuation of the water once in the wetland. These are some of the major environmental factors that control wetland functions (National Research Council 1995).

Gwin et al. (1999) focused on HGM classifications of wetlands to determine how compensatory mitigation was affecting the wetland resource in and around Portland, Oregon. Classification of reference wetlands resulted in three regional HGM classes that were typical in the Portland metropolitan area: slope, riverine, and depressional. However, classification of mitigation wetlands

> *required development of new, atypical HGM classes to describe the unique combinations of site morphology and landscape setting found in these wetlands:*
>
> - *depression-in-riverine setting,*
> - *in-stream-depression, and*
> - *depression-in-slope setting* (Gwin et al. 1999).

Atypical refers to created or enhanced wetlands that do not match the geomorphic setting, water source, and/or hydroperiod found within the range of existing wetlands in a region. Gwin et al. (1999) characterized atypical classes by:

- Exaggerated depressional morphology with steep banks
- Large areas of open and/or deep water
- A large berm isolating the wetland from an adjacent stream channel
- Excavation within the stream channel producing an open water area wider and deeper than the original stream

In Washington 35% of compensatory mitigation projects resulted in wetlands of an atypical HGM class (Johnson et al. 2002). In Portland, Gwin et al. (1999) found that almost all of the enhanced wetlands and nearly half of the created wetlands resulted in an atypical HGM class.

What are the hydrologic consequences of creating atypical wetlands in the landscape? Shaffer et al. (1999) examined hydrologic conditions in reference and mitigation wetlands in the Portland metropolitan area. The study compared the regional HGM classes identified by Gwin et al. (1999)—slope, riverine, and depressional—with the atypical classes for mitigation wetlands—depression-in-riverine setting, depression-in-slope setting, and in-stream-depression. The results indicated significant differences. For example, slope wetlands had the lowest extent, depth, and duration of inundation, "while depression-in-slope wetlands had the highest water levels and greatest extent/duration of inundation" (Shaffer et al. 1999).

Similarly, Cole and Brooks (2000) noted that created wetlands were dominated by open water, while "most naturally occurring mainstem floodplain wetlands in central Pennsylvania are vegetated with very little open water." The authors concluded, "in the rush to make sure there is some water in mitigation wetlands we have gone too far in keeping sites inundated. In reality, many wetlands are merely saturated, or much drier" (Cole and Brooks 2000).

Schaffer et al. (1999) state:

> *Unless wetlands are restored or created in a manner that reproduces the hydrogeomorphic characteristics of naturally occurring wetlands in a region, management activities are unlikely to maintain or replace hydrologic and other valued functions of wetlands*.

Similarly, Cole and Brooks (2000) conclude:

> *The ecological consequences of a different hydrologic regime are clear. Standing water will promote anaerobic conditions in the soil, and the resulting soil chemistry will be defined by anaerobic pathways (Mitsch and Gosselink 1993). When combined with other common construction effects (e.g. soil compaction), this leads to difficult conditions for plant community establishment.*

In addition, water regimes exhibiting extensive areas of open water in mitigation wetlands hindered the formation of soil organic matter (Shaffer and Ernst 1999).

6.8.6 Summary of Key Points

- Functions performed and characteristics produced by created, restored and enhanced wetlands differed from those performed and produced by reference wetlands, except water quality functions, which appeared to be performed in a similar capacity.

- Most studies determined that reference wetlands provided habitat for a greater diversity or abundance of wildlife than created or restored wetlands. Birds were an exception since half of the studies found no difference between created/restored sites and reference wetlands, particularly for ducks.
- A variety of factors appeared to influence the abundance and diversity of wildlife at created or restored wetlands: development of vegetation communities, particularly emergent vegetation communities; age of the wetlands, which is often associated with the development of vegetation communities; and availability of a food source, often invertebrates, which is also often associated with the development of vegetation communities.
- Amphibian communities were affected by additional factors, such as the hydroperiod of the wetland, the presence of fish, distance to other wetlands, connectivity between terrestrial and wetland habitats, and surrounding land uses.
- Created and restored wetlands have different vegetation characteristics and plant communities than reference wetlands. A few studies found that certain plant communities, such as sedge meadows, may require many years to develop, if they develop at all.
- Compensatory mitigation is producing more acreage of open water wetlands than was lost. The ability of compensatory mitigation to produce other Cowardin classes varied.
- Several major factors were found to affect vegetation and plant communities, including the age of the wetland (older created/restored sites had a higher percent cover of emergent and woody species than younger sites); soil conditions (positive effects on vegetation resulted from adding hydric topsoil); competition (reed canarygrass can be problematic when attempting to establish emergent vegetation); and a source of native seeds or plants (this may speed up recolonization and increase diversity).
- Created, restored, and enhanced wetlands had less organic matter than reference wetlands. In addition, organic matter at compensation wetlands did not appear to accumulate over time. Plant establishment at compensation sites could be hindered by the low organic content in conjunction with soils that were found to be sandier, more compacted, and lower in nitrogen than soils at reference wetlands.
- Created and restored wetlands were comparable to reference wetlands at retaining sediments, phosphorus, and nitrogen. Factors affecting sediment and nutrient retention included the volume of water flowing into the wetland, the length of time water remains in the wetland, and the size of the wetland compared to the size of the basin.
- Some compensatory mitigation wetlands produced different HGM classes than were present in reference wetlands. This has resulted in wetlands that have more inundation for a longer duration than reference wetlands.

6.9 Reproducibility of Particular Wetland Types

This section discusses findings from the literature regarding the ability to restore, create, or enhance certain wetland types, such as bogs and fens, vernal pools, alkali wetlands, and mature forested wetlands.

6.9.1 Bogs and Fens

Bogs and fens are characterized by their highly organic soils, water regimes, and water chemistries. There were no studies of bog or fen restoration conducted in the Pacific Northwest. However, studies of bog and fen restoration in Northern Europe and Canada concluded that restoration may not be possible due to "irreversible changes of the biotic and abiotic properties" (Schouwenaars 1995, Schrautzer et al. 1996). This includes soil compaction and eutrophication (Grootjans and van Diggelen 1995, Schrautzer et al. 1996, Wind-Mulder and Vitt 2000) and other alterations to bogs resulting from drainage, peat harvesting, pollution, and agricultural practices (National Research Council 2001).

The studies mentioned difficulties in restoring bog vegetation communities (Bolscher 1995, Grosvernier et al. 1995, Schouwenaars 1995, Schrautzer et al. 1996), water regime (Grootjans and van Diggelen 1995, Schouwenaars 1995), and/or water chemistry (Wind-Mulder and Vitt 2000). Major conclusions include the following:

- Restore the water regime and the vegetation community will follow (Grootjans and van Diggelen 1995, Grosvernier et al. 1995).

- Prior to any restoration activity, the chemical state of the bog must be assessed. This influences the vegetation community and will, therefore, dictate the development of a restoration plan (Wind-Mulder and Vitt 2000).

- "Hydrological research may be crucial for a correct assessment of perspectives for rewetting" (Schouwenaars 1995). Prior to restoration it is necessary to determine the reason for a low water table because this affects the activities that will be required to restore a suitable water regime for the desired vegetation communities (Schouwenaars 1995).

- Bogs that were restored by rewetting and tree removal "differed from those of natural raised bogs, particularly in having taller and denser vegetation, a smaller range of moisture gradient and a more uniform vegetation physiognomy. Rewetted bogs did not have an undulating surface relief of hummocks and hollows" (Bolscher 1995).

- The best chance for restoration lies with restoring the least disturbed or damaged bogs or fens (Grootjans and van Diggelen 1995, Schrautzer et al. 1996).

- Restoration of bogs or fens will not yield rapid results (Grootjans and van Diggelen 1995).

- "Research has demonstrated that natural recovery of the moss surface following harvesting takes about 20 years (Elling and Knighton 1984)" (National Research Council 2001).

In terms of creation, research indicates that in reference systems organic soil (peat) accumulates at 0.1 to 3.8 mm per year (National Research Council 2001). At this rate it would take from 7 to 250 years for just 1 inch of peat to accumulate.

No information was available on the success or compliance of bogs or fens that were restored or created as wetland compensation. However, the literature suggests that bogs and fens cannot be reproduced within a regulatory timeframe.

6.9.2 Vernal Pools

Vernal pools are characterized by their short duration of inundation (National Research Council 2001). Thus, in order to reproduce a vernal pool, a site with a suitable substrate must be found and the correct depth and hydroperiod must be created or restored (National Research Council 2001). "In a long-term study of California vernal pools that were created by excavating depressions near natural pools, the hydroperiods did not converge with those of the reference systems until year 10 (Zedler et al. 1993)" (National Research Council 2001). If the hydroperiod is too long, the result will be an emergent marsh or an open water or aquatic bed system. If the site has inadequate substrate or is too shallow, the result may be upland with no inundation.

In terms of compliance, De Weese (1998) examined over 1,500 created vernal pools in California. She found that 83% of projects were in permit compliance, 96% met their hydrologic performance standards for depth of inundation, and 69% met vegetation performance standards. Seventy-two percent of projects were compared with reference vernal pools to determine their biological viability, while 35% of projects required some site remediation.

Guidance on construction has helped to transform the steep-sided "bathtubs" into pools that more closely mimic reference pools with gradual, vegetated slopes (De Weese 1998). De Weese (1998) concluded, "The art and science of constructing vernal pools have greatly improved over the past eight years [1987 to 1994]."

The literature suggests that, in California, vernal pools may be reproduced under the right conditions. However, the right conditions typically occur where vernal pools already exist, so creation of new pools merely increases the density of pools in an area (National Research Council 2001).

No information was found on the reproducibility of vernal pools in Washington.

6.9.3 Alkali Wetlands

No information was found that addressed the reproducibility of alkali wetlands.

6.9.4 Mature Forested Wetlands

Though studies have found that forested wetlands can be reproduced in Washington (Celedonia 2002, Johnson et al. 2002), *mature* forested wetlands have not been successfully reproduced simply because of the time necessary for the trees and the structural characteristics of the forest to mature (National Research Council 2001). Enhanced and created sites that have been planted often have a high density of stems to rapidly provide woody cover and shade out invasive species in the understory (Celedonia 2002, National Research Council 2001). Within a regulatory time-frame, compensatory mitigation wetlands may not begin to reproduce some of the attributes of mature forested reference wetlands unless these sites are thinned (National Research Council 2001).

6.9.5 Summary of Key Points

- The reproducibility of some wetland types is generally dependent upon time. For example, bogs, fens, and mature forested wetlands require several decades at a minimum, and possibly centuries, to develop the structural, chemical, biological, and hydrological attributes that characterize these wetland types.
- Studies suggest that vernal pools, at least in California, may be reproducible under the right conditions.

6.10 Suggestions from the Literature for Improving Compensatory Mitigation

A number of reports and articles suggested or recommended changes that could be made to help improve the effectiveness of compensatory wetland mitigation or alleviate problems that were frequently encountered. The recommendations described below are those of the authors of the literature sources cited, not the agencies or staff who have synthesized the information in this volume.

Data from a variety of sources are summarized throughout this section in a series of tables. To simplify the tables and efficiently use space, each literature source listed in the tables is represented by a reference number listed in Table 6-10. This is not a comprehensive list of all references cited in this section; see the references section at the end of Volume 1 for a complete list of literature sources.

Table 6-10. Literature sources and corresponding reference numbers.

Reference No.	Literature Source	Reference No.	Literature Source
1	Allen and Feddema (1996)	19	Shaich and Franklin (1995)
2	Balzano et al. (2002)	20	Storm and Stellini (1994)
3	Brown (1999)	21	Ossinger (1999)
4	Ashworth (1997)	22	Wilson and Mitsch (1996)
5	Erwin (1991)	23	Barry et al. (1996)
6	Gwin and Kentula (1990)	24	Castelle et al. (1992a)
7	Holland and Kentula (1992)	25	Celedonia (2002)
8	Holland and Bossert (1994)	26	Chovanec (1994)
9	Johnson et al. (2000)	27	Hunt et al. (1999)
10	Johnson et al. (2002)	28	Kentula (2000)
11	Stauffer and Brooks (1997)	29	National Research Council (2001)
12	Kentula et al. (1992)	30	Race and Fonseca (1996)
13	Kunz et al. (1988)	31	Sheldon and Dole (1992)
14	Shaffer and Ernst (1999)	32	Whittecar and Daniels (1999)
15	Michigan Department of Environmental Quality (2000)	33	Zedler and Callaway (2000)
16	Mockler et al. (1998)	34	Mitsch and Wilson (1996)
17	Morgan and Roberts (1999)	35	Breaux and Serefiddin (1999)
18	Robb (2002)	36	Kellogg and Bridgham (2002)

The scientific literature contained recommendations that fall into three main categories:

- Recommendations for regulators of compensatory mitigation, including guidance on mitigation plans and monitoring reports, compliance tracking and enforcement, and alternative mitigation options
- Recommendations for site selection and design, including comprehensive wetland planning, baseline monitoring, hydrologic analysis, and considerations for site design
- Recommendations for implementing compensatory mitigation, including having a wetland biologist on-site to oversee construction activities, performing monitoring and maintenance of the site

The scientific literature provided more extensive information on additional topics:

- Performance standards
- Compensatory mitigation using a watershed approach
- Mitigation banking and in-lieu fees

Each of these is discussed below.

6.10.1 Regulatory Improvements

Of the suggestions provided by the scientific literature, the majority focused on elements that regulatory agencies should address (Table 6-11), such as:

- Improving guidance for every step of the mitigation process, from avoidance and minimization to submitting a monitoring report for a compensation wetland. This should help regulators with decision-making and provide applicants and consultants with more predictability
- Adjusting replacement ratios to reflect the risk of failure
- Requiring financial assurances or performance bonding
- Protecting all compensatory mitigation sites in perpetuity with a legal mechanism, such as a deed restriction or conservation easement
- Increasing regulatory follow-up and enforcement of compensatory mitigation projects, including developing and maintaining a database and filing system, allocating staff to perform compliance and enforcement activities, and implementing reviews of regulatory program performance
- Developing and implementing alternative mitigation options, such as advance mitigation, mitigation banking, and in-lieu fees

Table 6-11. Suggestions from the literature for regulatory improvement.

Suggestion	Reference No. [a]
Improve mitigation sequencing (i.e., avoidance and minimization)	5, 19, 29, 2, 10
Improve guidance for compensation projects, focusing on replacing functions as well as area	22, 29, 10
Improve site selection criteria. Site selection should be based on a watershed scale to maintain diversity, connectivity, and a balance of upland and wetland	5, 12, 15, 29, 2, 10
Improve goals, objectives, and performance standards, so that they are measurable, meaningful, achievable, and enforceable	13, 5, 31, 20, 19, 17, 9, 29, 10, 21
Standardize report format and elements for mitigation plans and monitoring reports, including an implementation schedule	13, 7, 8, 20, 17, 15, 2, 10

Suggestion	Reference No. [a]
Adjust (increase) replacement ratios to reflect the risk of failure. This should be based on the level of success of previous projects	1, 2, 18
Require performance bonding/financial assurances	13, 5, 8, 20, 15, 29, 2, 18
Require that compensation wetlands be protected in perpetuity with some kind of legal mechanism, such as a deed restriction or conservation easement	20, 29
Improve regulatory follow-up and enforcement of compensatory mitigation projects	5, 20, 19, 1, 30, 17, 15, 9, 29, 10, 18
Develop and maintain a permit/compensatory mitigation project tracking database and filing system	5, 7, 20, 19, 1, 17, 9, 15, 29, 2
Allocate staff for compliance and enforcement	5, 19, 17
Implement regular reviews of regulatory program performance	7, 19, 2
Implement studies of cumulative wetland loss (beyond what is recorded for regulatory permitting programs)	19, 1
Develop and implement alternative compensatory mitigation options: in-lieu fees, mitigation banking	20, 19, 1, 15, 29
Perform the compensatory mitigation in advance of the wetland loss	30, 29, 10, 18
[a] See Table 6-10 for a listing of literature sources that correspond to each reference number.	

6.10.2 Improving Site Selection and Design

The scientific literature also suggested site selection and design considerations (Table 6-12), including:

- Using a watershed approach to improve site selection
- Prioritizing wetland restoration
- Performing baseline monitoring of the wetland to be lost, identifying the wetland types and functions so that they can be replaced more effectively
- Performing baseline monitoring of the areas proposed for compensation to document the existing conditions and level of function
- Performing a hydrologic analysis for compensation wetlands to identify where the water will come from, how it will get to the site, and what the extent and duration of inundation or saturation will be
- Designing the compensation site to be self-sustaining and incorporating or simulating natural processes and structures, such as hydroperiods, slopes, shorelines, soils, topography, and vegetation

Table 6-12. Suggestions from the literature for improving site selection and design.

Suggestions	Reference No.[a]
Ensure that compensation wetlands will have a suitable source of water and compatible adjacent land uses	5, 28, 17, 29, 2, 10
Use a watershed approach to select compensation sites and support comprehensive wetland planning	19, 1, 28, 17, 29, 10
Prioritize restoration as the first choice for compensatory mitigation	17, 15, 29
Design compensatory mitigation wetlands to be self-sustaining and incorporate natural processes whenever possible	33, 29
Perform baseline monitoring of wetlands to be lost and areas proposed for compensatory wetland mitigation. Monitoring should characterize hydroperiod, soils, water quality, macroinvertebrates, and wetland functions	13, 5, 31, 20, 29, 10
Perform hydrologic analysis: identify hydrologic source, how water will get to the site, the intended depth and duration of inundation, and demonstrate that water source will be reliable and adequate Determine appropriate hydroperiod/hydrologic inputs early in the design stage, so that the water levels of the compensation wetland dictate how to design the building sites and roads, rather than letting the upland development create poor wetland conditions (too wet or too dry)	5, 31, 16, 28, 2
Grade slopes to be as gentle as possible; they should match the slopes of adjacent natural wetlands	6
Provide heterogeneous topography. For example, simulate microtopographic “mound and pool” features (e.g., wind-thrown or toppled trees)	23, 29
Incorporate native upland ecosystems into compensatory mitigation sites	5, 29
Deconsolidate (i.e., break-up) soils to reduce compaction and amend to insure adequate soil organic matter (e.g., 2 inches of coarse sand and 4 inches organic compost, natural hydric muck, or topsoil)	6, 16, 28, 32, 14
Take advantage of native seedbanks, natural recruitment, and salvaged topsoil and plants when available and feasible	29, 3, 4, 11
Minimize human encroachment by planting dense vegetation around the site or installing fences	26, 20, 16
Establish rapid canopy convergence and limit invasive species infestations by planting trees and shrubs at specific densities	25
Indicate the boundaries of the site with signs and markers	20, 16
[a] See Table 6-10 for a listing of literature sources that correspond to each reference number.	

6.10.3 Improving Implementation

Compensatory wetland mitigation projects would be greatly improved if they were implemented as designed (Johnson et al. 2000, Balzano et al. 2002). The scientific literature provides numerous suggestions for improving implementation (Table 6-13), such as:

- Having a wetland biologist on-site during construction
- Monitoring the compensation wetland
- Develop an adaptive management plan that allows potential problems to be detected early and identifies how problems will be addressed
- Maintaining the compensation wetland to avoid problems and manage them early in the development of the site

Table 6-13. Suggestions from the literature for improving implementation.

Suggestion	Reference No.[a]
Wetland biologist on-site to oversee construction or train/educate contractors and to authorize and document any necessary changes	5, 31, 9, 2
Monitoring of mitigation sites should characterize baseline, construction, as-built, and post-construction conditions. Monitoring reports should include a section on lessons learned	13, 6, 5, 24, 7, 31, 8, 20, 19, 15, 9, 2, 10
Monitoring parameters and methods should be specific to a project's goals, objectives, and should include: project size, shape, topography, hydroperiod, water quality, flora, and fauna	5, 17, 33
Monitor compensatory mitigation wetlands. Duration of monitoring may range from 3 to more than 20 years, depending on the size of compensation wetland, the proposed wetland type (e.g., Cowardin class), and the likelihood of success	5, 34, 35, 17, 15, 10, 29, 36
Monitor hydrology during the first growing season to characterize the site's hydroperiod. Develop and implement a planting plan after the hydroperiod has been characterized	27
Perform long-term monitoring after a project has been deemed successful to keep track of it over time, study how it matures, use it as model for other sites	5, 28, 36
Develop an adaptive management program, which includes early monitoring of wetland structure, processes, and functions to detect potential problems and allow for corrective actions	29
Maintain compensatory mitigation sites, including a contingency plan for how to address problems. Maintenance should focus on controlling invasive species, providing irrigation, replacing dead plants, correcting slopes and topography	13, 24, 31, 8, 2, 10, 29

[a] See Table 6-10 for a listing of literature sources that correspond to each reference number.

6.10.4 Performance Standards

Performance standards, performance criteria, success criteria, success measures, standards of success, and other terms all refer to regulatory conditions used to determine how effective a mitigation project is at meeting regulatory requirements, which may or may not include compensating for wetland loss. Ideally performance standards should serve as “measurable benchmarks used to evaluate the development of ecological characteristics associated with specific wetland functions” (Azous et al. 1998). Performance standards allow regulators to determine if a compensatory mitigation project has fulfilled its goals, and also provide a mechanism for regulators to implement enforcement actions against unsuccessful projects (Streever 1999).

As explained in Chapter 2, wetlands differ in how they function, by geomorphology and water regime and other characteristics. Compensatory wetland mitigation projects, likewise, exhibit considerable variability with different types of wetland compensation (creation, restoration, etc.). The variability makes it difficult to develop and require universal performance standards, yet in the absence of some kind of uniformity, performance standards that are approved can lack meaning.

6.10.4.1 Shortcomings of Existing Performance Standards

Sheldon and Dole (1992) performed a study of eight compensatory mitigation projects in King and Snohomish Counties in Washington. The authors observed that “none of the goal statements provided a quantifiable method of determining success, thus they provided no means for an agency to assess success/failure or to require remediation.” The Michigan Department of Environmental Quality (2000) similarly found, “The practice of including no specific performance standards, or only very general performance standards (regarding the size and possibly the type of wetland to be constructed), resulted in many unenforceable permits and contributed to the poor quality mitigation wetlands.”

Johnson et al. (2000), in their study of 45 compensatory mitigation wetlands, noted some problems with performance standards, such as:

- Standards that are too general or “easy to attain” and, therefore, are not indicative of ecological development at a site
- Standards that are not measurable and, therefore, cannot be used to evaluate the success or compliance of projects
- Standards that contain confusing or ambiguous language and, therefore, result in inaccurate assessment or preclude assessment

In addition, Johnson et al. (2002) in their evaluation of 24 compensation projects excluded performance standards that were unrealistic, not feasible, or so rigorous that the standard may never be attained. Such standards were “. . .setting sites up for failure” and therefore “. . .did not reflect how the site was functioning or progressing ecologically”

(Johnson et al. 2002). Ossinger (1999), in a guidance document for the Washington State Department of Transportation, suggests that performance standards should strike a balance between accountability and flexibility. The author recommends that crafting performance standards requires a technical knowledge of the quantitative values that are achievable, or to be expected, for the wetland attributes targeted by the standard.

Approved mitigation projects can also lack performance standards for important wetland functions or conditions. Breaux and Serefiddin (1999) discovered in their review of 110 projects in San Francisco, California, that only 22% had quantitative standards focusing on hydrological parameters. Johnson et al. (2000) reviewed 179 performance standards from 36 projects and observed that 8% of the performance standards related to hydrological conditions. The Michigan Department of Environmental Quality (2000) found that "none of the permits examined contained any specific criteria regarding vegetation or hydrology by which the mitigation wetland could be judged for success or failure." Johnson et al. (2002) noted that most of the projects evaluated in their study of 24 compensation wetlands lacked basic standards for wetland area, water regime, area of Cowardin classes, percent cover of native wetland vegetation, and maximum percent cover of invasive vegetation.

Breaux and Serefiddin (1999) argue, "In seasonal wetlands, hydrology clearly ought to be the reigning criterion given that the successive presence and absence of water is the defining characteristic of a seasonal wetland." However, the authors go on to admit, "there is no agreement as to what the specific hydrological criterion should be."

6.10.4.2 Use of Reference Wetlands in Developing Performance Standards

Brinson and Rheinhardt (1996) state that "the proper use of reference wetlands removes potential bias and provides the foundation for more objective functional-assessment procedures…reference wetlands should be central to the development of standards against which impacts to wetlands and restoration efforts are evaluated."

Azous et al. (1998) also support the use of reference wetlands:

> *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.*

For example, a compensation wetland might have a goal to provide amphibian habitat by the end of the monitoring period. Based on an evaluation of 24 depressional, flow-through, reference wetlands in the Puget Lowlands of western Washington, Azous et al. (1998) proposed performance standards to determine if amphibian habitat had successfully been established. "The standards include specific guidelines for planning and designing mitigation projects to provide preference for the establishment of amphibian breeding, feeding, and refuge habitats." The authors suggested the following standard, "Wetlands created for amphibian habitat should have thin-stemmed emergent plants that comprise at least 30% or more of the total wetland area (Azous et al. 1998)."

However, Whittecar and Daniels (1999) mention a problem with using reference wetlands to develop benchmarks or performance standards for compensatory mitigation:

> *[U]nlike the mitigation site, reference wetlands coexist with landforms that may have required thousands of years to form (Brinson et al. 1995). Each wetland has a history that influences modern functions. Many of these functions will not redevelop in the new wetland within a time span acceptable to regulatory constraints without thoughtful planning and careful attention to construction.*

Ehrenfeld (2000) recommends that reference sites be identified in urban areas and used to develop attainable performance standards for compensatory wetland mitigation projects that are also located in urban areas. The author states: "Measures of restoration success and functional performance must start with an appreciation and assessment of the particular conditions imposed by the urban environment."

6.10.4.3 Longer Period Needed to Evaluate Projects

Part of the problem with developing achievable performance standards is that monitoring periods or regulatory timeframes for the majority of compensatory mitigation projects are relatively short (five to 10 years). The "success" or compliance of compensatory mitigation projects is, therefore, determined or evaluated when the site is still relatively young and immature (Kentula 1995, Mitsch and Wilson 1996). Longer monitoring periods are necessary to allow for secondary succession and natural events (e.g., drought or floods) that may affect or restructure vegetation communities (Kellogg and Bridgham 2002). Long term monitoring would also result in larger data sets upon which realistic performance standards and project goals could be based (Kellogg and Bridgham 2002).

If projects are to be evaluated within five to 20 years, then they should be compared to other compensatory mitigation projects. Kentula (1995) suggests comparing "wetland creation and restoration projects to each other and to similar, naturally occurring wetlands to define standards for project performance over time." She describes an approach for developing performance standards based on monitoring information from previous projects. "In this way, we can be assured that new projects are doing at least as well as past projects."

Celedonia (2002) implemented Kentula's approach by conducting a study of 29 compensatory mitigation projects from six to 11 years old in the lowland wetlands of western Washington. Time series curves were created from the data to determine at what point in time projects could be expected to meet certain vegetative standards, such as percent areal cover of woody vegetation. Based on the data, the author proposed that by year eight a mitigation site could attain 80% cover of native woody vegetation.

6.10.5 Compensatory Mitigation Using a Watershed/Landscape Approach

In the context of compensatory mitigation, a watershed approach means:

> *to recognize that management of wetland types, functions, and locations requires structured consideration of watershed needs and how wetland types and location serve these needs. A watershed approach means that mitigation decisions are made with a regional perspective, involve multiple agencies, citizens, scientists, and nonprofit organizations, and draw upon multiple funding sources (e.g., permittee-responsible, mitigation banks, and in-lieu fees). A watershed approach means that permitting decisions are integrated with other regulatory programs (e.g., storm water management or habitat conservation) and nonregulatory programs (e.g., conservation easement programs)* (National Research Council 2001).

Bedford (1996) explained the need for a watershed/landscape approach as follows:

> *From a policy perspective, the central issue in wetland mitigation is not the effects on a single site but the cumulative effect of numerous mitigation decisions on landscapes. Mitigation must be recognized as a policy that has the potential to re-configure the kinds and spatial distribution of wetland ecosystems over large geographic areas. … The net effect is the loss of wetland diversity in terms of both hydrologic functions and biological communities, and a consequent homogenization of wetland landscapes. One way to avoid such cumulative effects is to make decisions about individual projects within a framework focused at larger scales (Lee and Gosselink 1988).*

This section describes recommendations from the literature for methods to implement a landscape or watershed-scale approach in order to improve the success of mitigation projects. Further discussion of restoration using a landscape approach is included in Chapter 7 in the context of addressing cumulative impacts to wetlands.

6.10.5.1 Methods for Implementing a Landscape Approach

Three types of watershed planning are described in a report by the National Research Council (2001):

- **Management-oriented** wetland planning, which would replace case-by-case permitting. Decisions about permitting, mitigation sequencing, and the acreage, type, and location of compensation would be made in advance using a watershed approach. This type of watershed plan would require regulatory and non-regulatory programs to be coordinated.

- **Protection-oriented** wetland planning, which is focused on avoiding wetland loss and alteration by identifying wetlands and their ecological value. This type of watershed plan would be used during the mitigation sequencing process.

- **Compensation** wetland planning, which "identifies watershed needs for types, functions, and general locations of wetlands in the landscape in order to establish restoration priorities for both regulatory and nonregulatory programs. …This type of planning might link projects undertaken through both regulatory and nonregulatory programs to secure some desired mosaic of wetlands in the landscape."

Hashisaki (1996) discusses the utility of a landscape-level analysis to examine conditions not just at an impact, compensation, or reference site, but also in the surrounding landscape. A landscape-level analysis "considers the effect of historic, current, and proposed land management practices on the individual functional indicators. . . . In addition to identifying constraints on land management practices, it can be useful in identifying critical preservation and restoration opportunities. Understanding the control that human activities exert on the disturbance regimes of an ecosystem allows projections about expected future conditions."

Bedford (1996) recommends developing wetland profiles/templates based on the diversity of wetland types that exist in a region as a result of the unique interaction of hydrogeology and climate. By understanding the current and historic wetland types and their relative abundances in a region, decisions regarding compensatory mitigation can be made to help maintain the diversity and hydrologic equivalence.

In some cases, using a watershed approach may result in a watershed plan that identifies all the wetlands in an area and assesses the functions that they perform. Hruby and Scuderi (1995) used this approach for a watershed near Seattle, Washington, that was experiencing development pressure. The goal of the plan was "to ensure that the performance of wetland functions and their societal values continue to be equal to or greater than those currently existing…" (Hruby and Scuderi 1995). Wetland areas targeted for restoration or enhancement were assessed to quantify how much wetland function could be gained. The proposed/potential gain in function through restoration/enhancement could then be used to determine how much wetland function could be lost to development activities in the watershed.

A report by the National Research Council (2001) proposed that "Functional tradeoffs might be considered in the context of the needs of the watershed." A watershed plan would be developed for an area, such that the functions of wetlands proposed for loss or alteration are understood, as well as the needs of the watershed for wetland functions. Functions that are abundant or a low priority in a watershed could be lost and replaced by other functions that are limited or a higher priority in the watershed.

Race and Fonseca (1996) point out that on a national level, a landscape approach to land use and compensation would require the cooperation/participation of thousands or millions of private landowners:

> *Taking a large-scale, ecosystem approach to wetlands management is a significant change in natural resource management policies, one representing a major paradigm shift that will require radical revision in values, management practices, and institutional structures in order to succeed (Cortner and Moote 1994). …Thus, integrating ecologically relevant concepts such as landscape-scale decision criteria need more than good science; it will also require conscious redesign of the entire permitting infrastructure to avoid legal challenges.*

6.10.6 Mitigation Banking

Compensatory mitigation banking and other third-party compensation approaches (in-lieu fee, market-based mitigation) are believed by some to provide part of a solution and have offered new hope for successful compensation of wetland impacts (Kukoy and Canter 1995).

Currently, even when wetlands have been avoided or established as compensation they often “have diminished ecological functions from polluted runoff, from changes in hydrologic regimes, and from the fragmentation of the landscape which isolates the wetlands from the surrounding uplands, water, and biological resources of the watershed” (Shabman et al. 1993).

In addition, some federal, state, and local permits for wetland loss do not require compensatory mitigation because the individual impact is so small that compensation is considered impractical, despite the fact that cumulative losses are occurring (Shabman et al. 1993, Kukoy and Canter 1995, Weems and Canter 1995). Finally, even when compensatory mitigation is required there is no guarantee that it will be implemented or successful.

Shabman et al. (1993) outlined a market solution to improve compensatory wetland mitigation. Market-based mitigation approaches start with an entrepreneurial restoration firm seeking to make a profit from selling a product—a wetland ecosystem. If the product is not of a particular quality then it will not sell. For example, if the wetland bank is not in compliance, not meeting its performance standards, or not providing the proposed functions then the regulatory agencies will not accept credits from the bank as compensation for wetland losses. The permit applicant, therefore, will not purchase the “product” of the wetland bank. This is the incentive for the restoration firm to establish a functioning wetland ecosystem.

In addition, a restoration firm can take the time to find a suitable location for the wetland that will minimize problems with fragmentation (Kukoy and Canter 1995). Wetland banks can also secure large sites for restoration that would not be feasible on a small project scale (Weems and Canter 1995).

Once the wetland is established, credits or tradable portions of the wetland can be made available for purchase to compensate for wetland losses (Weems and Canter 1995), even wetland losses that were previously too small to require compensation (Kukoy and Canter 1995). It is assumed that the availability of bank credits for compensation can also provide efficient permitting since the applicant would not have to worry about getting a mitigation plan approved, and regulators could more readily assess the effectiveness of the compensation.

Mitigation banking in Washington State has been more thoroughly discussed in the *Draft Programmatic Environmental Impact Statement: Washington State's Draft Rule on Wetland Mitigation Banking* (Driscoll and Granger 2001, available at: http://www.ecy.wa.gov/biblio/0106022.html). For additional information on mitigation banking and in-lieu fee programs refer to *Banks and Fees: The Status of Off-Site Wetland Mitigation in the United States* (Environmental Law Institute 2002).

6.10.7 Summary of Key Points

- The scientific literature provided suggestions for improving virtually every aspect of the mitigation process from regulatory guidance and policies to specifications for controlling invasive vegetation.
- Suggestions included measurable, meaningful, achievable, and enforceable performance standards; better sites that provide increased benefits due to their location within a watershed; better monitoring of compensatory mitigation wetlands; and measures to increase regulatory follow-up of compensation projects.

6.11 Chapter Summary and Conclusions

Wetland compensatory mitigation has been studied in Washington and elsewhere in the United States for the past 15 years. Considerable data are available to evaluate the effectiveness of compensatory mitigation.

The majority of compensatory wetland mitigation projects described in the literature was neither fully successful nor completely unsuccessful. Most projects were found to have an intermediate level of success. While most compensatory mitigation projects were installed, compliance of the projects with permit requirements was generally low. The authors of Volume 1 hypothesized that this was due to shortfalls of wetland acreage, failure to achieve performance standards, and a lack of monitoring and maintenance. The few studies that examined the effect of regulatory follow-up suggested that it had a positive influence on the level of compliance and success for compensatory wetland mitigation projects.

There is a general lack of information about the relative effectiveness of the various types of compensation (e.g., restoration, creation, enhancement, etc.). Creation is generally the most frequently used type of compensation, but studies of its effectiveness produced mixed results. Enhancement of wetlands was also frequently used, but few studies examined its effectiveness. Limited studies from Washington indicated a low level of success among enhanced wetlands, primarily due to a minimal gain in functions. Restoring wetlands was noted as a high priority, but as a type of compensation it is not frequently used.

Preservation and a mixture of compensation types appear to be used occasionally. Studies provided limited information on the effectiveness of these types. Two studies from Washington indicated that mixed compensation projects had a higher level of compliance than creation or enhancement, and all mixed projects were moderately successful. The lack of data regarding the effectiveness of preservation is problematic since one of the only studies to look at its effectiveness determined that one large site was predominantly upland habitat. On the other hand, if a site can be confirmed as wetland, or if a mosaic of wetland and upland is determined to be acceptable, preservation of existing wetlands offers no risk of failure and no temporal loss of wetland functions, which are inherent in the other types of compensation. Preservation does, however, result in a net loss of wetland area and possibly functions.

Replacement ratios attempt to equalize the trade-off between the wetland being lost and the wetland being provided as compensation by accounting for the risk of failure and temporal loss of functions. Required replacement ratios vary from one state to another, based on the type of compensation proposed, and based on project-specific circumstances. Replacement ratios actually achieved through compensation were less than what was required, which is to be expected since the ratios are meant to encompass a certain level of failure. However, in some cases this resulted in less than 1:1 acreage replacement.

Studies relying solely on permit files and databases indicated that permitting programs have improved over time in terms of wetland acreage required for compensation. However, studies which relied on site visits and field analyses indicated that compensatory wetland mitigation has resulted in a loss of wetland acreage.

Functions performed and characteristics produced by created and restored wetlands differed from those performed and produced by reference wetlands, except water quality functions, which appeared to be performed in a similar capacity. None of the studies compared the functions provided by compensation wetlands with the functions provided by the wetlands that were lost.

For the most part, reference wetlands provided habitat for a greater diversity or abundance of wildlife than created or restored wetlands. Birds were an exception since half of the studies found no difference between created/restored sites and reference wetlands, particularly for ducks. Created and restored wetlands have different vegetative characteristics and plant communities than reference wetlands. Certain plant communities, such as sedge meadows, may require many years to develop if at all.

The authors of Volume 1 conclude that the common finding that wetland compensation sites have greater vegetation species richness is linked to the broad range of niches created on a new site. A newly created or restored site is a “blank slate” upon which species will be planted, species from the previous habitat on the site will re-emerge, and species adapted to disturbance will colonize. Over time the site will stabilize and mature and only the species adapted to the resulting conditions will remain. However, research on restored, created, or enhanced sites that have stabilized is currently lacking. One could infer, therefore, that sites are not studied for a long enough time, due either to the relatively short regulatory timeframe or the decades or lifetimes necessary to achieve stabilization and maturity.

Researchers observed that created, restored, and enhanced wetlands had less organic matter than reference wetlands. This could be due to the excavation of surface soil layers during project construction. Studies also indicated that organic matter at compensation wetlands did not appear to accumulate over time. Therefore, plant establishment at compensation wetlands could be hindered by low organic content in conjunction with soils that were found to be sandier, more compacted, and lower in nitrogen.

Compensatory mitigation is producing more acreage of open water wetlands than was lost. The ability of compensatory mitigation projects to produce other Cowardin classes varied. Some compensatory mitigation wetlands have produced different HGM classes than were present in the reference wetlands. This has resulted in wetlands that have more inundation for a longer period than reference systems.

Some unique types of wetlands, such as bogs, fens, and mature forested wetlands, may not be reproducible, especially not within current regulatory timeframes. Other wetland types, such as vernal pools, may be reproducible given the right conditions.

The literature provided numerous suggestions on virtually every aspect of the mitigation process. Key suggestions include:

- Improving regulatory guidance on a variety of topics, such as measurable, meaningful, achievable, and enforceable performance standards for compensatory mitigation
- Finding better sites that provide increased benefits due to their location within a watershed
- Monitoring compensatory mitigation wetlands more effectively
- Implementing measures to increase regulatory follow-up of compensation projects

The literature suggests that some improvements have been made in compensatory mitigation over the past two decades, particularly in terms of what is required. However, overall success and permit compliance have not noticeably improved. Most studies indicate that created and restored wetlands do not provide the same characteristics or level of functions as reference wetlands (water quality functions may be the exception).

Since the effectiveness of compensatory mitigation remains highly variable and somewhat questionable, it is increasingly important to understand the cumulative effects of the continuing loss of wetland acreage and functions. This will be addressed in the next chapter.