Developing Defensible Wetland Mitigation Ratios

A Companion to "The Five-Step Wetland Mitigation Ratio Calculator"

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1. INTRODUCTION

The Problem

NOAA is asked frequently to make recommendations regarding permit applications for development projects that will adversely affect coastal wetlands. Because coastal wetlands are scarce and important to fisheries and other marine resources, and are at risk from unavoidable hazards such as sea level rise, NOAA usually recommends that these permits be denied. Despite NOAA's objections, however, many of these projects are permitted as long as permit-seekers agree to mitigate adverse wetland impacts by undertaking wetland creation, restoration, or enhancement projects. In these cases, the most effective fall-back strategy for NOAA is to exert as much influence as possible over the quantity and quality of wetland mitigation that is provided to offset "unavoidable" wetland impacts.

The cost of providing wetland mitigation depends on the **quality** of mitigation that is required, which is reflected in spending per acre; and the **quantity** of mitigation required, which is reflected in the number of acres of mitigation required per acre of wetland impact. As restoration standards have evolved to improve the **quality** of mitigation, the economic incentives for permit seekers to try to hold down the **quantity** of mitigation required by regulators has increased. NOAA's role, and the role of other resource agencies involved in managing wetland mitigation, is to assure that the stronger economic incentives that permit seekers and mitigation providers have to control costs do not result in wetland mitigation that fails to replace lost wetland functions and services. However, in the absence of technically and legally defensible methods for comparing the functions and values of impacted wetlands with those from mitigation wetlands, it is difficult for NOAA to play its essential role of imposing quality control on wetland mitigation.

This paper describes an analytical tool that can be used to develop wetland mitigation ratios that are technically and legally defensible, and are based on achieving "full" replacement of lost wetland services. The tool can be used to establish appropriate ratios for specific wetland permitting decisions, to "score" wetland mitigation trades, or to assign "credits" to wetland mitigation banks. Using the tool, in most cases, will result in higher mitigation requirements than not using the tool. Using the tool also provides economic incentives for developers to avoid and minimize wetland impacts. Because the tool links the quantity of mitigation required (number of acres) to the quality of mitigation offered (gains in wetland services per acre), it also provides economic incentives for developers who cannot avoid wetland impacts to invest in higher quality wetland restoration.

The Policy Context

Most state and federal wetland policies involve a three stage process known as "sequencing" which requires wetland permit seekers to: *avoid* wetland impacts if possible, *minimize* unavoidable wetland impacts to the maximum extent "practicable", and *mitigate* any remaining wetland impacts. In principle this approach makes sense (MOA, 1990). The costs and delays associated with the third stage of permitting, wetland mitigation, provide at least some economic incentives for land developers to avoid and minimize wetland impacts. And, as long as wetland mitigation actually offsets unavoidable wetland losses, the approach results in "no net loss" of wetlands without preventing worthwhile coastal economic development that really cannot be designed to fully avoid wetlands.

Use of Economic Analysis

NOAA can use economic analysis to provide more protection for wetlands during the first two stages of sequencing by more carefully scrutinizing the documentation that permit-seekers provide to permitting agencies to show that they are avoiding and minimizing wetland impacts. However, undeveloped coastal lands in most areas are so scarce that developers who apply for wetland permits probably have exhausted their options to avoid and minimize wetland impacts, and can prove it. Other than stopping potentially worthwhile economic development or public works projects that result in "unavoidable" wetland impacts, therefore, the only option for NOAA and other regulatory agencies is to allow these projects with acceptable mitigation. So, it is often during the third stage of sequencing, when permit seekers are arranging to provide mitigation for unavoidable wetland impacts, that NOAA can most usefully apply economics to help prevent losses of wetland functions, services, and values. Where opposing a proposed wetland development project cannot succeed, in other words, the next-best strategy for NOAA to protect wetland services is to impose quality control on the wetland mitigation associated with the project.

After describing the policy context of wetland mitigation and the challenges it poses to wetland regulators, this paper describes and illustrates a technically and legally defensible approach that NOAA field staff can use to impose quality on wetland mitigation. The paper is a companion to "The Five-Step Wetland Mitigation Ratio Calculator" which is a spreadsheet-based tool for applying the approach.

Mitigation Context

Wetland mitigation is a sound idea and there are many specific examples of wetland impacts that have been successfully mitigated. However, virtually every review of wetland mitigation over the past twenty years has shown that overall wetland gains resulting from mitigation projects have not adequately offset overall wetland losses that are resulting from permitted wetland development (NRC 2001, OPPAGA 2001, King 1997). According to these reviews the problems with wetland mitigation fall into two categories: 1) the number of acres of wetlands provided as mitigation is less than the number of wetland acres impacted; and 2) where mitigation does result in at least “one-for-one replacement” in terms of wetland acres, differences in wetland quality between the lost and replacement wetlands result in a net loss of wetland functions and services.

Our national wetland mitigation policy is logical, in other words, on both economic and environmental grounds; but it is apparently being implemented in a way that is resulting in a steady loss of valuable and often irreplaceable wetlands. In terms of wetland services, if not in terms of wetland area, this policy, as it is currently being applied, is failing to achieve our national goal of “no net loss.”

Source of the Problem

Wetland experts often attribute the problems with wetland mitigation to our limited understanding of wetland restoration science and technology and our inability to measure and compare the value of wetlands. The argument here is that wetland mitigation is failing because we do not know how to create or restore wetlands and cannot measure what is important about them. However, most reviews of wetland mitigation failures indicate that this is probably a secondary issue, and that mitigation fails most often because wetland mitigation projects were not designed to succeed, were not implemented properly, or were located where site conditions or landscape factors prevented them from succeeding. While there are limits to restoration science and technology that will always limit mitigation success, the evidence indicates that the real problem is not these limits, but perverse economic incentives in wetland mitigation markets. Mitigation providers have strong economic incentives to lower permitting costs by providing the lowest quality mitigation that wetland regulators will allow; and mitigation regulators do not have the tools they need to impose quality control on mitigation or to provide countervailing economic incentives that promote high quality mitigation.

Measuring Mitigation Success

Normal markets are more or less self-regulating as buyers and sellers compete with each other over price and quantity. Wetland mitigation markets, however, are very different. Sellers of mitigation (e.g., mitigation contractors and, more recently, mitigation bankers) and buyers of mitigation (e.g., real estate developers, state DOTs) actually have more economic incentives to work together to keep mitigation costs low than they have to compete with one another. Both buyers and sellers of mitigation tend to be only as concerned about mitigation quality as mitigation regulators or the rules governing mitigation require them to be. In this market situation the high level of confusion and uncertainty about the relative “value” of different types of wetlands (e.g., restored vs. natural, urban vs. rural, tidal vs. non-tidal, vegetated vs. mud) is an advantage to those interested in controlling permitting costs and has contributed to widespread mitigation failure. Uncertainty about wetland values has made it nearly impossible for regulatory agencies to use conventional economic arguments to justify imposing quality control on wetland mitigation. It has also made it difficult for resource agencies to argue that any acre of wetland creation, restoration, or enhancement that is offered as mitigation is worth any less than the acre of natural wetland it is supposed to offset.

Worsening this problem is the fact that in most regulatory and judicial settings the burden of proof is not on permit-seekers to demonstrate that one-for-one wetland mitigation will result in no net loss of wetland services, but on the wetland regulators to show that proposals that involve one-for one mitigation will result in losses in wetland functions and values.. The "value-free" bio-physical indicators of wetland function that are preferred by wetland scientists may be useful for making certain wetland comparisons, but they have not been useful as a legitimate basis for determining the adequacy of mitigation, establishing how much money permit-seekers should spend on mitigation, or deciding how liability for mitigation failures should be assigned to buyers or sellers.

Underlying the high failure rates associated with wetland mitigation is another economic reality that buyers and sellers of wetland mitigation and most regulators understand. The cost of wetland restoration projects that have a reasonable chance of providing wetland services that are "equivalent" to those that are lost when a natural wetland is lost can be enormous, and are often prohibitive. None of the groups involved with wetland mitigation want standards that are so strict that they will close out the option of using mitigation to resolve wetland permitting problems. As long as the standards for what constitutes acceptable mitigation are kept vague, on the other hand, it is possible to control mitigation costs, and claim to be achieving the national "no net loss" wetland goal without anticipating any technical or legal challenges.

In summary, the root source of the problem with our national wetland mitigation policy is that the rules governing mitigation trading have evolved primarily to keep the cost of mitigation affordable and to make our national wetland policy appear to be successful. Tools that help insure that wetland gains from mitigation actually offset wetland losses are not available, and are not popular with mitigation traders or with many wetland regulators. Despite protests to the contrary, the powerful interests involved in wetland mitigation prefer using ad hoc (political) negotiations over what constitutes acceptable mitigation to strict (accounting-based) trading rules. If trade regulators had the political support and technical tools to negotiate effectively this would be an acceptable situation, but they do not. This is why formula-based mitigation trading rules like the one developed later in this paper are so important.

Proposed Solution

Ultimately debates over wetland values and the "equivalency" of wetland gains and losses from mitigation are usually reduced to establishing a "compensation ratio", a number that establishes the number of mitigation acres required per acre of wetland impacts. The implicit quantity/quality tradeoff inherent in the use of compensation ratios strikes some as illogical (e.g., how many acres of created mudflats are equivalent to an acre of mature mangrove?). However, if the compensation ratio is developed in a way that compares gains and losses in expected streams of wetland services it can be used effectively to both protect wetlands and manage wetland mitigation. For example, using conventional methods of dealing with differences in the timing and riskiness of wetland services provided by lost and replacement wetlands, it is relatively easy to establish that many acres of a young, restored wetland will be needed to provide the equivalent "value" of an acre of mature, natural wetland. Such a comparison, in economic terms, is not much different than comparing how many shares in a risky start-up company (e.g., a penny stock) would be equal, in terms of expected earnings over time, to a share in a mature, proven company (e.g., a blue chip stock).

The approach to establishing wetland mitigation ratios that is described here and can be made operational using "the five-step wetland mitigation ratio calculator" is based on the universal "net present value" approach to asset valuation. This approach is used routinely to compare the values of all kinds of manufactured assets and financial assets, and has withstood countless technical and legal challenges for at least a century. The approach provides a credible, practical, and defensible way for NOAA to impose quality control on wetland mitigation. The spreadsheet tool for applying the approach is easy to use and focuses attention on a few key characteristics about the impacted wetland and the replacement or mitigation wetland that determine the relative "value" of the streams of wetland services they are expected to provide over time.

Applications of the Tool

The tool requires users to set numerical values for eight parameters associated with impacted and the mitigation wetlands. These values can be generated in many different ways, but the most likely approach will involve expert consensus. Once these parameters are determined, the tool can be used in one of three ways: 1) to establish compensation ratios for a particular mitigation proposal or trade, 2) to establish the number of credits associated with "consolidated" mitigation projects or mitigation banking ventures, and 3) to influence the outcome of ad hoc negotiations over what constitutes acceptable wetland mitigation. Because the approach establishes the quantity of mitigation required (acres) on the basis of the quality of the mitigation provided (expected service flows per acre) it also provides incentives for mitigation providers to improve the quality of the wetland mitigation they provide in order to reduce the quantity of mitigation they will be required to provide.

Format of Paper

The remainder of the paper contains sections that: describe the economic basis for establishing mitigation ratios; define some key variables; and present and illustrate the use of a "universal" wetland mitigation ratio estimating equation. The main body of the paper is then followed by Appendix A, a four-page print-out from an interactive spreadsheet program called "the five-step wetland mitigation ratio calculator"; Appendix B, The effects of time discounting on the estimation of mitigation ratios; Appendix C, the effects of landscape context on the estimation of mitigation ratios; and Appendix D, a list and set of references for over 50 Wetland Assessment Methods that can be used with "the five-step wetland mitigation ratio calculator". Information for determining which wetland assessment method is most suitable under particular circumstances is beyond the scope of this paper, but interested readers should consult Bartoldus (1999).

2. BACKGROUND

Economic Basis of Mitigation Ratios

Differences in a wetland's condition and location can result in significant differences in the functions, services, and values it provides; an immature wetland also provides fewer ecosystem services than an older mature wetland. To account for these differences in wetland quality, most wetland regulatory institutions use mitigation ratios to adjust the number of acres gained and lost as a result of mitigation trades. This ratio is calculated as the number of acres of created, restored or enhanced wetlands required as mitigation for each acre of natural wetland being impacted.

From an economic perspective these ratios reflect a type of quantity-quality tradeoff. Where two assets involved in a trade are of equal value, whether they are wetlands or financial instruments, they can be fairly traded on a one-for-one basis. Where they are not of equal value, some type of quality/quantity adjustment is typically used to even out the trade. In principle, the mitigation ratio is intended to balance gains and losses since the wetland functions and services associated with an acre of created or restored wetland are usually expected to be less than those associated with a natural (impacted) wetland. Of course, in cases where the impacted wetland is already severely degraded or is in an inferior location it is reasonable to expect that the appropriate compensation ratio could be less than one-for-one.

In general, the mitigation ratio is supposed to be an aggregate index that allows the quantity of wetlands gained and lost to be adjusted to account for differences in wetland quality that result in differences in the streams of ecosystem services they are expected to provide over time.

The Use of Mitigation Ratios

A national review of 68 wetland mitigation banks (Brown and Lant, 1999) determined that the mean mitigation ratio used to score wetland mitigation trades in the U.S. was 1.36:1, based on the number of trades, and 1.41:1 when trades were weighted by wetland area. That is roughly 1.4 acres of created or restored wetland for each acre of natural wetland destroyed. The review also showed that "the majority of wetland mitigation banks use a 1:1 ratio, accounting for 73% of all the acreage."

One-to-one is a surprisingly low "typical" compensation ratio, especially considering that the sample of mitigation projects used in the study had the following characteristics: creation (25%), restoration (49%), enhancement (15%), preservation (12%)[1]. Wetland restoration projects are inherently risky, and it takes time for even successful wetland restoration projects to achieve full functional capacity. Also, providers of mitigation are not expected to receive "credit" for wetland functions that exist at the mitigation site prior to mitigation. If these factors were considered, one would expect to almost never encounter a mitigation ratio of 1:1. In fact, using an economic approach to establishing mitigation ratios based on asset values, such as the one described and illustrated below, a ratio of 1:1 can only result in "no net loss" of wetland function and value in the unlikely event that each acre of proposed mitigation provides full, immediate, and riskless replacement of all wetland services provided by each acre of impacted wetland.

One reason that prevailing compensation ratios are inconsistent with asset-based trading is that wetland scientists and environmental protection advocates have generally viewed all wetlands as valuable, and have strongly resisted attempts to classify one wetland as being any more or less valuable than another. While this position may have prevented "low-valued" wetlands from being "cherry picked" for development, it has also backfired by providing no technical basis for distinguishing between the "value" of wetlands for purposes of managing mitigation. The result has been that compensation ratios used to guide wetland mitigation trades

[1] These percentages are taken directly from Brown and Lant (1999) and sum to 101%, presumably because of rounding error.

have been based, in most regulatory settings, on political negotiations and ad hoc criteria, rather than sound science or asset based economic tools.

In some cases political negotiations have resulted in official mitigation ratio tables that are used routinely by regulators and specify ratios for specific types of mitigation (e.g., 1.2:1 for restoration projects, 2:1 for enhancement projects). In these cases, reliance on fixed compensation ratios rather than ad hoc negotiations seems to impart an element of fairness and predictability to the setting of compensations ratios. It is also convenient for regulators and permit-seekers. However, a system that establishes fixed mitigation ratios based on ad hoc negotiations also gives lawyers and regulators a great deal of discretion in establishing the terms of mitigation trades, including who bears the risks of failure. Permit-seekers and mitigation providers who constantly strive to keep compensation ratios and associated mitigation costs low do so, at least in part, by managing the expectations of regulators and political leaders concerning what are viewed as "excessive" mitigation costs. As quality standards for wetland restoration work become more standard, costs per acre become less negotiable. Keeping mitigation costs low, therefore, requires low mitigation ratios which can be achieved more easily through ad hoc negotiations than strict "asset-based" decision rules.

Elements of Mitigation Ratios

To account for differences in the ecosystem services provided per acre by impacted and replacement wetlands, a mitigation ratio should take account of five factors:

1. The *existing level* of wetland function at the site prior to the mitigation;
2. The *resulting level* of wetland function expected at the mitigation site after the project is fully successful;
3. The *length of time* before the mitigation is expected to be fully successful;
4. The *risk* that the mitigation project may not succeed; and
5. Differences in the *location* of the lost wetland and the mitigation wetland that affect the services and values they have the capacity and opportunity to generate.

3. PROPOSED FRAMEWORK

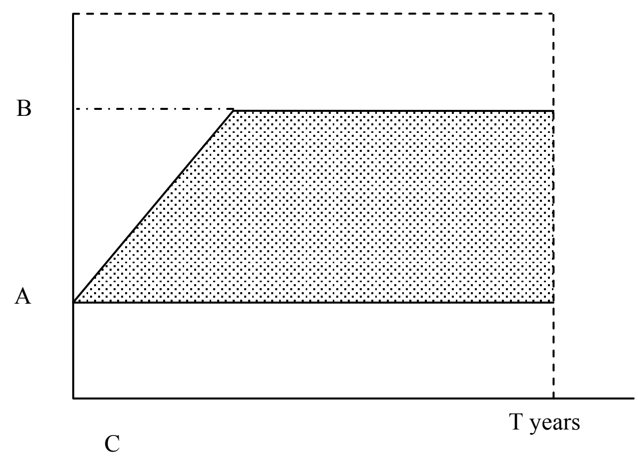
This section illustrates the proposed method by defining the necessary conditions for one-for-one mitigation to provide adequate compensation for lost wetland services, and then incrementally considering how the five factors listed above should be considered to establish compensation ratios that will provide "full" mitigation under more realistic assumptions.

Necessary Conditions for 1:1 Mitigation

For sake of illustration consider the depiction of a wetland mitigation project shown in Figure 1. The project is characterized using three parameters, A, B. and C, where: A represents the level of wetland services at the mitigation site prior to mitigation expressed as a percent of the level of wetland services at the wetland impact site; B represents the maximum level of wetland services with mitigation expressed in the same way; and C is the number of years expected for wetland services to increase from A to B.

Under the situation described above, the box outlined in Figure 1 represents the 100% loss of annual wetland services per acre of wetland over T years at the wetland impact site, and the hatched area represents the amount of offsetting annual wetland services provided per acre by the mitigation project over T years. The white area represents the lost wetland services that are not mitigated with one-for-one mitigation because it existed at the site prior to the mitigation project (the area below A) or will not be attained after the mitigation (the area above B). The ratio of the white area to the boxed area, therefore, is the percent loss in wetland services with one-for-one mitigation.

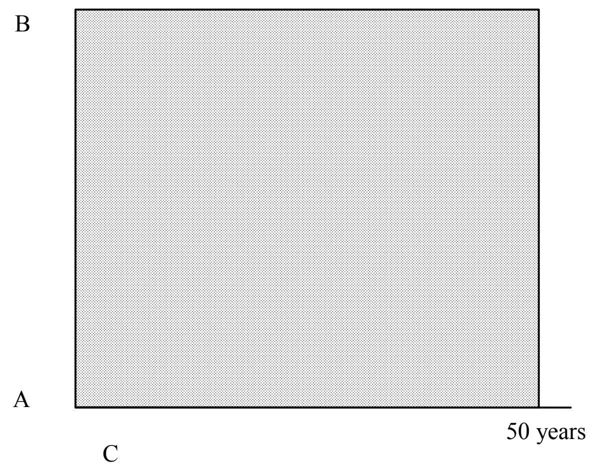
Figure 1.



Now consider Figure 2, which depicts the conditions under which a mitigation ratio of 1:1 would provide no net loss in wetland services. If we ignore the potential risks of mitigation project failure, achieving no net loss of wetland services with acre-for-acre mitigation would require that three conditions be met.

1. In the absence of the mitigation activity, the wetland services provided at the mitigation site are negligible (A ≈ 0).
2. With mitigation, each acre of mitigation produces wetland services that fully replace those associated with an acre of wetland loss at the wetland impact site (B = 100% or more); and
3. The mitigation site generates these full replacement wetland services instantly as soon as it is constructed (C = 0);

Figure 2. T_{max} = 50 years
B = 1, all other parameters = 0



Mitigation Ratio = 1:1

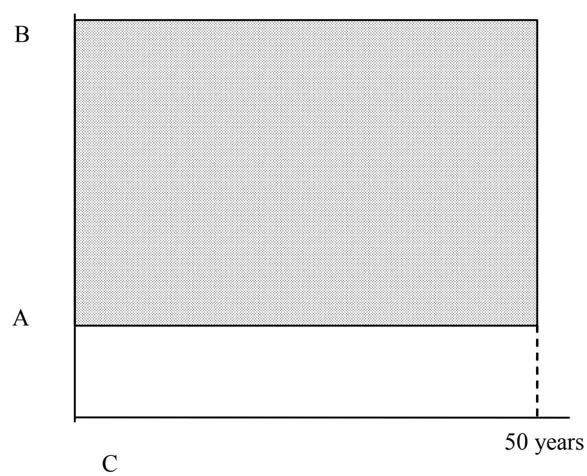
Obviously, the scenario depicted in Figure 2 is highly unlikely which calls into question the widespread use of 1:1 mitigation ratios to score wetland mitigation bank trades. More typical scenarios based on more realistic values of A, B, and C and a few other parameters are described below.

More Typical Mitigation Conditions

In typical mitigation situations that involve wetland restoration, rather than wetland creation there is already some level of wetland function at the mitigation site (A>0); the restored wetland cannot reach maximum function immediately (C>0), and the function of the mitigation wetland may never equal that of the impacted wetland (B< 100%).

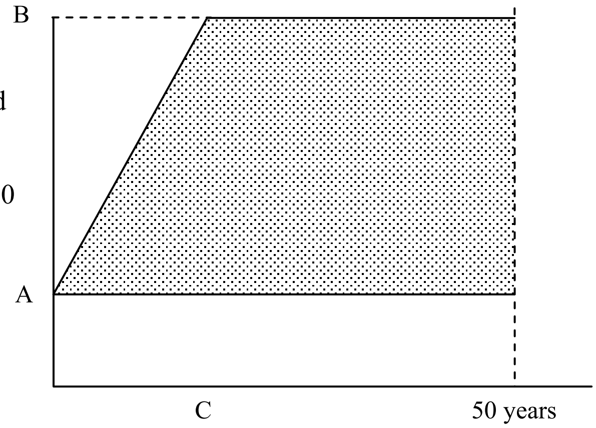
Figures 3, 4 and 5 incrementally add factors that should be reflected in mitigation ratios and show how the shaded area, depicting the amount of mitigation, changes. Figure 3 shows that not giving "credit" for existing wetland function at the mitigation site (area below A) increases the mitigation ratio. Figure 4 shows that if the mitigation project does not achieve full function immediately (C>0) the mitigation ratio is even higher. Figure 5 shows that if the stream of wetland services from the mitigation wetland after mitigation is less than that of the impacted wetland the appropriate mitigation ratio is still higher.

Figure 3. Accounts for existing wetland function
T_{max} = 50 years
A = 0.25, B = 1.0



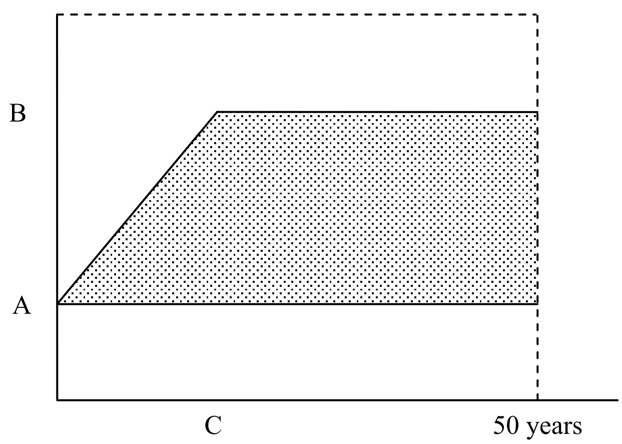
Mitigation Ratio = 1.33:1

Figure 4. Accounts for time to achieve function and existing wetland function
T_{max} = 50 years
A = 0.25, B = 1.0 and C = 10



Mitigation
Ratio = 1.77:1

Figure 5. Accounts for restoration limits, time to achieve function and existing wetland function
T_{max} = 50 years
A = 0.25, B = 0.75, C = 10



Mitigation
Ratio = 2.66:1

The A, B, C Framework

The framework outlined above is relatively simple to apply. Since the shaded area depicts the value provided by an acre of mitigation and the entire rectangle from T_0 to T_{max} depicts the values lost with each acre of the lost wetland, dividing the shaded area by the total area gives the percentage of wetland value compensated with 1:1 mitigation. The inverse of this percentage gives an estimate of the "appropriate" compensation ratio. A 50% loss on an acre-for-acre basis requires a mitigation ratio of 2, compensating 66.6% of wetland value requires a mitigation ratio of 1.5, compensating only 33.3% of wetland value requires a mitigation ratio of 3, and so on.

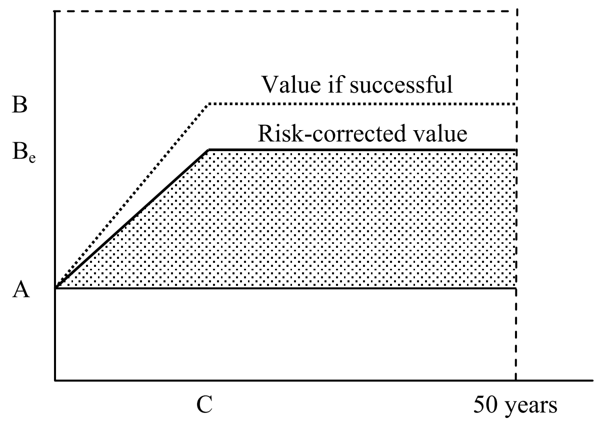
The percentage loss in wetland value with acre-for-acre mitigation depends directly on the values of A, B, and C; and the mitigation ratio, the number of acres of mitigation required to generate no net loss in the stream of wetland services gained and lost over time, is also based on A, B, and C.

Other important Factors to Consider

The simple A, B, C framework misses a few important considerations; namely the timing, risk, and landscape context of the mitigation. A more complete version requires adding parameters to account for these three additional considerations, which can be defined as follows:

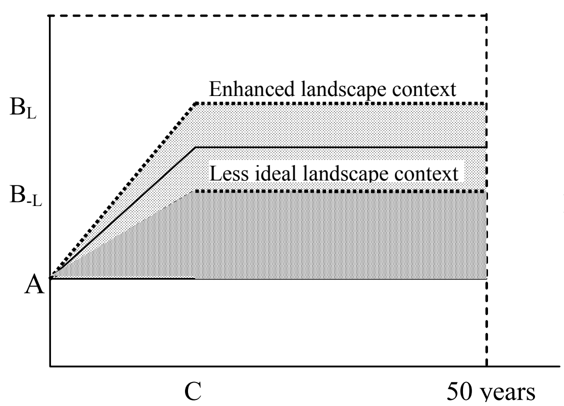
1. *risk* – that a wetland creation or restoration project will not perform as well as expected. Figure 6 illustrates the effect of considering risk in calculating the mitigation ratio.
2. *landscape context*[2] – to account for differences in landscape context of impacted and mitigation wetlands. Figure 7 demonstrates that enhanced or less-ideal landscape conditions can alter the mitigation ratio in either direction.
3. *advanced or delayed compensation* – the possibility that a mitigation project may be completed and begin providing replacement wetland value either before or after the loss of the original wetland;

Figure 6: Accounts for risk of failure, restoration limits, time to achieve function and existing wetland function
T_{max} = 50 years
A = 0.25, B = 0.75, C = 10, E = 0.15



Mitigation Ratio = 3.43:1

Figure 7: Accounts for landscape context, risk of failure, restoration limits, time to achieve function and existing wetland function
T_{max} = 50 years
A = 0.25, B = 0.75, C = 10, E = 0.15, L = 0.3 or L = -0.3



Mitigation Ratio $L_{0.3}$ = 2.30:1

Mitigation Ratio $L_{-0.3}$ = 6.78:1

4. THE COMPENSATION RATIO FORMULA

Equation Parameters

Introduction of a few new parameters that consider time, the risk that the mitigation will fail, and landscape context into the simple A, B, C framework completes the picture. When these factors are all included in a compensation ratio formula it begins to look like a relatively standard version of the universally used "net present value" formula, which is used to evaluate

[2] For more information on how landscape context should factor in to decision making in wetland mitigation, see Appendix C.

all types of investments. The problem of monetary valuation is avoided because we are comparing the streams of services from impacted and replacement wetlands in relative terms.

Using the formula, which is presented below, requires the user to estimate or settle upon acceptable values of the following parameters:

- *A:* The level of wetland function provided per acre at the mitigation site prior to the mitigation project, expressed as a percentage of the per acre value of the original wetland;
- *B:* The maximum level of wetland function each acre of mitigation is expected to attain, if it is successful, expressed as a percentage of the per acre value of the original wetland;
- *C:* The number of years after construction that the mitigation project is expected to achieve maximum function;
- *D:* The number of years before destruction of the original wetland that the mitigation project begins to generate mitigation values (negative values represent delayed compensation);
- *E:* The percent likelihood that the mitigation project will fail and provide none of the anticipated benefits (with mitigation failure, wetland values at the mitigation site return to level A);
- *L:* The percent difference in expected wetland values based on differences in landscape context of the mitigation site when compared with the impacted wetland (positive values represent enhanced landscape context at mitigation site);
- *r* : The discount rate used for comparing values that accrue at different times at their present value (tables provide estimates based on discount rates of 0%, 5%, and 10%);
- T_{max}: The time horizon used in the analysis. (Using the OMB recommended discount rate of r=7% comparisons of value beyond about t=75 years are of negligible significance).

Under the circumstances described above the discrete time equation that can be used to solve for the appropriate mitigation ratio is as follows:

$$R = \frac{\sum_{t=0}^{T_{\max}} (1+r)^{-t}}{\left(B(1-E)(1+L) - A\right)\left[\sum_{t=-D}^{C-D} \frac{(t+D)}{C(1+r)^{t}} + \sum_{C-D+1}^{T_{\max}} (1+r)^{-t}\right]}$$

5. ILLUSTRATIONS

Table 1 shows some calculated compensation ratios based on the compensation formula. The first three cases show the effects on the resulting compensation ratio of delaying or advancing the compensatory mitigation project. The next three examples illustrate how preexisting wetland values at the mitigation site or compensation for the loss of a degraded wetland affect compensation requirements. The third set of examples demonstrates the effect of landscape context on the mitigation ratio. The final set of examples illustrates how the assessment of failure risk can affect the estimated compensation ratio.

The basic characteristics of the mitigation project itself, as reflected in the values of A, B, and C are obviously important in determining the appropriate compensation ratio. The last example shown in Table 1, however, illustrates why advanced mitigation should provide a significant advantage over concurrent mitigation in terms of compensation requirements. Since many mitigation failures can (1) be detected, and (2) be corrected within a year or so of project construction, advanced compensation allows mitigation providers to manage many controllable risk factors and significantly lower the risk of failure. At the same time, advanced mitigation provides replacement wetland values sooner than concurrent mitigation, so there is less discounting of replacement values and more resulting mitigation provided per acre. Combined, these factors result in a substantial advantage for advanced mitigation as compared to concurrent or delayed mitigation in terms of the number of mitigation acres required. Lower compensation ratios for advanced mitigation mean lower mitigation costs, which in many cases could more than offset the cost of committing funds for advanced mitigation or investing in a mitigation bank.

Table 1. Calculated compensation ratios for a variety of hypothetical compensation scenarios, based on a time horizon (T_{max}) of 50 years.

							COMPENSATION RATIOS		
	Parameters						Discount Rate		
	A	B	C	D	E	L	0%	5%	10%
Concurrent Creation	0	0.7	10	0	0	0	1.6	1.9	2.3
Advanced Creation	0	0.7	10	5	0	0	1.4	1.5	1.4
Delayed Creation	0	0.7	10	-5	0	0	1.8	2.5	3.8
Concurrent Restoration	0.1	0.7	10	0	0	0	1.9	2.2	2.7
Original Wetland Degraded	0	1.4	10	0	0	0	0.8	1.0	1.2
Concurrent Enhancement	0.4	0.7	10	0	0.2	0	7.0	8.3	10.2
Concurrent, Enhanced Landscape	0	0.7	10	0	0	0.3	1.2	1.5	1.8
Concurrent, Less ideal Landscape	0	0.7	10	0	0	-0.3	2.3	2.7	3.3
Difficult Creation	0	0.7	10	0	0.5	0	3.2	3.8	4.7
Very Difficult Creation	0	0.7	10	0	0.75	0	6.4	7.6	9.4
Same, Advanced & Risk Adjusted	0	0.7	10	5	0.2	0	1.8	1.8	1.8

6. ESTIMATING PARAMETERS

The most direct way to estimate the relative value of wetlands is to start with conventional wetland functional capacity indices, such as those developed through Hydrogeomorphic Method (HGM) or Wetlands Rapid Assessment Process (WRAP), and extend them to consider the effects of landscape context on expected level of function (e.g., rate of functional capacity utilization) and related services, values, and risk. The recommended method is based on three sets of wetland site capacity adjustment indices, including:

1. *Functional Capacity Utilization Index* – Indicators of landscape conditions that determine how much of the functional capacity of the site is likely to be used.
2. *Service Value Index* – Indicators of landscape conditions that limit or enhance the level of services expected per unit of function (output per unit capacity) or the expected value per unit service (value per unit output)
3. *Service Risk Index* – Indicators of the likelihood of future disruptions in service flows that affect the value of expected wetland services. These are related to the exposure and vulnerability of the site or other critical landscape features to such threats as floods, droughts, fire, disease, infestations, water diversion, pollution, and industrial development.

7. CONCLUSIONS AND RECOMMENDATIONS

The framework and formula described above and in the accompanying spreadsheet program are based on generally accepted economic concepts. However, the parameters used to estimate compensation ratios related to any particular project (e.g., A, B, and C) are based on wetland science, or at least the judgment of wetland scientists. It is useful to note that employing the formula allows mitigation providers the option of providing more mitigation by investing at either the intensive or extensive margin. For example, if the mitigation provider spends more per acre to increase the quality per acre of mitigation provided (e.g., higher B, lower C, or both), the mitigation ratio that reflects the number of acres required will decline. If the mitigation provider spends more on land (acres) and less on restoration efforts ($ per acre), the mitigation value per unit area will be lower and the required mitigation ratio (number of acres) will increase.

The proposed formula can serve several purposes. It can help prevent wetland mitigation trades that result in losses of wetland values and impose risks on the general public. It can make mitigation requirements more predictable and consistent for permit seekers. And, it can help mitigation providers understand the payoff from investing in wetland mitigation credits at the intensive margin (more $ per acre) or at the extensive margin (more acres). Finally, the formula also allows the level of wetland mitigation to be based on science and economics, not politics, and generates compensation ratios that will withstand most technical and legal challenges.

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APPENDIX A

Developing Defensible Wetland Mitigation Ratios

A Companion to "The Five-Step Wetland Mitigation Ratio Calculator"

Prepared by

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Next

APPROACH

Ultimately debates over wetland values and the “equivalency” of wetland gains and losses from mitigation are usually reduced to negotiations over a “compensation ratio”, a number that establishes the number of mitigation acres required per acre of wetland impacts. The implicit quantity/quality tradeoff inherent in the use of compensation ratios strikes some as illogical (e.g., how many acres of mud puddle are equivalent to an acre of mature mangrove?). However, there is one great advantage in using a compensation ratio to compare the values of lost and replacement wetlands. It is far easier to establish the “relative” value of one wetland compared to another than it is to establish the absolute (dollar-based) value of either of them. Similarly, it is much easier to establish how many acres of an inferior wetland (e.g., young, restored) provide equivalent value to an acre of a superior wetland (e.g., mature, natural). The comparison, in economic terms, is not much different than comparing how many shares in a risky start-up company (e.g., a penny stock) are equal, in terms of expected earnings over time, to a share in a mature, proven company (e.g., a blue chip stock). The approach to establishing wetland mitigation ratios proposed and described here is based on the universal “net present value” approach to asset valuation that has withstood countless technical and legal challenges over time. The approach is proposed here as a credible, practical, and defensible way to impose quality-control on wetland mitigation and help NOAA manage the quality as well as the quantity of wetlands that result from mitigation.

However, this approach is useful for other reasons as well. It focuses attention on wetland comparisons that are based the services and values wetlands are expected to provide over time, rather than purely bio-physical measures that are the focus of most wetland indicator systems. This should make the results of these comparisons more influential in legal and regulatory settings, where most wetland decisions about wetlands are made, than in scientific comparisons based on “value-free” criteria.

Next

Defintion of Terms and Generalized Equation

Using the formula requires the user to estimate or settle upon acceptable values of the following parameters:

A The level of wetland function provided per acre at the mitigation site prior to the mitigation project, expressed as a percentage of the per acre value of the original wetland;

B The maximum level of wetland function each acre of mitigation is expected to attain, if it is successful, expressed as a percentage of the per acre value of the original wetland;

C The number of years after construction that the mitigation project is expected to achieve maximum function;

D The number of years before destruction of the original wetland that the mitigation project begins to generate mitigation values (negative values represent delayed compensation);

E The percent likelihood that the mitigation project will fail and provide none of the anticipated benefits (with mitigation failure, wetland values at the mitigation site return to level A)

L The percent difference in expected wetland values based on differences in landscape context of the mitigation site when compared with the impacted wetland (positive values represent enhanced landscape context at mitigation site)

r The discount rate used for comparing values that accrue at different times at their present value

T_{max} The time horizon used in the analysis (Using the OMB recommended discount rate of r=7% comparisons of value beyond about t=75 years are of negligible significance)

Under the circumstances described above the discrete time equation that can be used to solve for the appropriate mitigation ratio is as follows:

$$R = \frac{\sum_{t=0}^{T_{\max}} (1+r)^{-t}}{\left(B(1-E)(1+L)-A\right)\left[\sum_{t=-D}^{C-D-1} \frac{(t+D)}{C(1+r)^{t}} + \sum_{C-D}^{T_{\max}} (1+r)^{-t}\right]}$$

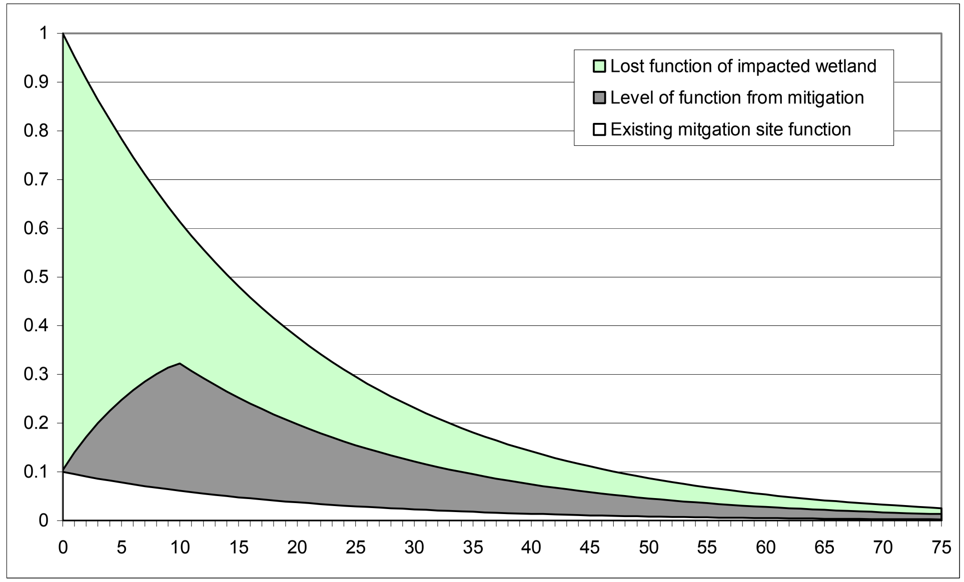
Advance to Calculator

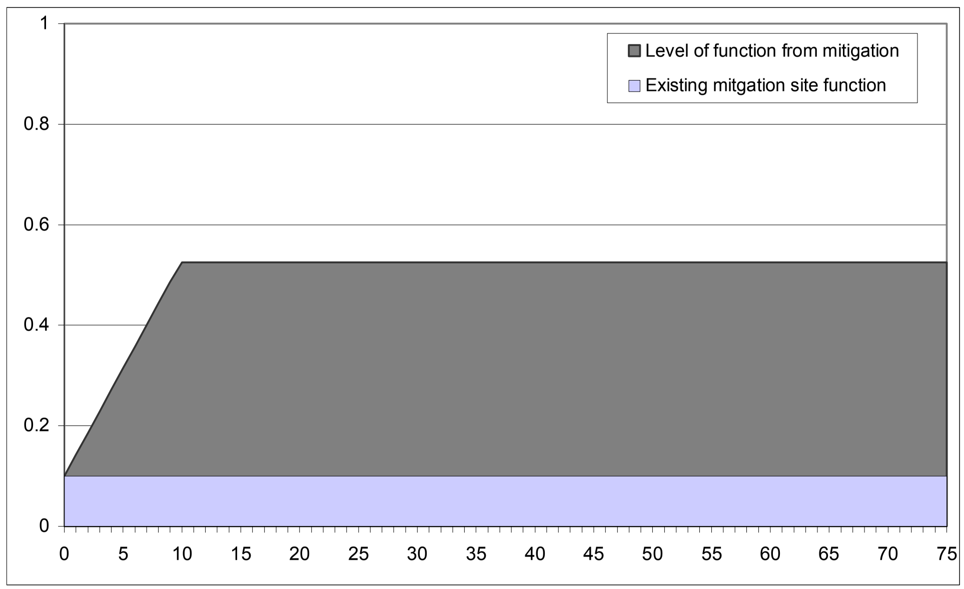
Enter Parameter Values

A	0.1
B	0.75
C	10
D	0.1
E	0
L	-0.3
r	0.05
Tmax	75

R = 3.05

Tmin 0
B' 0.525





APPENDIX B
Effects of Discounting on Mitigation Ratios

The Need to Compare Present Values

Not discounting the streams of wetland services to account for time differences implicitly assumes that replacement wetland services that will be realized as far as 50 years in the future are equal to wetland services lost today. In general, wetland-related benefits that accrue in the future, like the benefits from all other natural and man-made assets, are less valuable than those that accrue immediately. The concept of "discounting" cannot be described here, but it is used universally in economics to compare different streams of costs and benefits in "present value" terms and should be applied here to compare different streams of wetland benefits. To determine an appropriate compensation ratio, in other words, one must compare not only the magnitude of the values gained and lost, but also when the gains and losses accrue. Since concurrent mitigation means losing the benefits of a natural wetland now and having it replaced later after the compensatory wetland is established, discounting will usually result in higher compensation ratios than not discounting. Discount rates on the order of 5% to 10% per year are typical for most applications.

The effect of discounting on the stream of wetland benefits is illustrated in Figure B1. This curve represents a discount rate of 5% applied over 50 years. While the current value of the stream of benefits is 1.0, the present value of the stream of benefits 50 years from now is 0.09. The formula $\frac{1}{(1+r)^t}$ is used to calculate present value in year *t*, where *r* is the discount rate. The mitigation ratios in the following sections all reflect the application of a 5% discount rate.

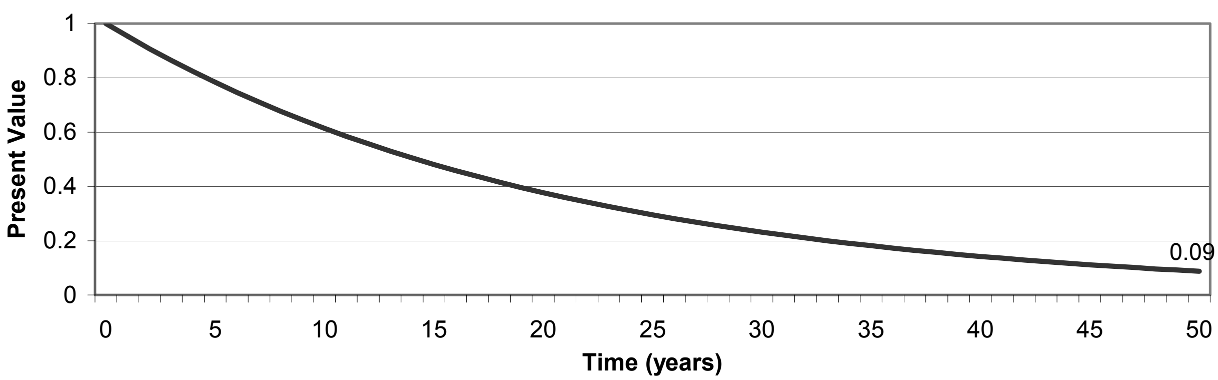


Figure B1. Effect of discounting present value over 50 years.

APPENDIX C

Effects of Landscape Context on Mitigation Ratios

Wetland location is included in the equation as a scalar of relative change in landscape context of the mitigation site with respect to the impacted wetland. Figure C1 illustrates the basis for considering landscape factors in the assessment of wetland mitigation trades. The wetland at Site A and the wetland at Site B in Figure C1 are shown to be identical in terms of size and shape. For sake of illustration assume that they are also the same type of wetland and are identical in terms of biophysical characteristics (e.g., soil, vegetation, hydrology). Consider a situation where Site B is a created or restored wetland that is offered as mitigation for the loss of Site A. Since we are assuming that the two sites are identical we are, for now, ignoring the temporal lag and risks associated with mitigation projects and focusing only on landscape factors that might influence the relative value of the two wetlands.

The factors listed above illustrate that the value of Site A, all other things equal, is greater than the value of Site B. They also provide evidence for a rebuttable presumption that a mitigation ratio used to "score" a trade that involves losing wetland area at Site A and gaining wetland area at Site B should be greater than 1:1. However, the existing landscape context of the two sites provides only part of the criteria for taking account of location. For sake of illustration, for example, consider additional evidence that Site B is located where it is more exposed to infestation (or re-infestation) from invasive species, or where it is more vulnerable to disruptions from planned water diversions or anticipated flooding. Consider also the possibility that a new regional 10-year plan designates the area around Site A as "environmentally sensitive—no-growth" and the area around Site B as "industrial—quick permitting." Any of these conditions would imply that Site A, already more valuable than Site B under current landscape conditions, is likely to be even more valuable in the future. The expected (risk-adjusted) value of each future stream of wetland services from Site A is greater than the expected value of an identical stream of services from Site B because the services from Site B are more likely to be disrupted.

Current Landscape Conditions

Since the wetlands at Site A and Site B are identical they have exactly the same *capacity* to provide all wetland function. A first approximation of the appropriate mitigation ratio based on site conditions alone, therefore, would be 1:1. Differences in the landscape contexts of Site A and Site B show that they can be expected to provide significantly different services and that the services they provide on a per unit basis are also likely to be different.

For example, consider how differences in landscape context of the two sites would affect their relative value with respect to three specific functions: wildlife habitat, fishery support, and water quality improvements. Even though the two wetland sites are shown to be relatively close to one another (on either side of Route #66) consider the following differences which affect their relative value:

- Site A has more opportunity than Site B to provide wildlife support because it is accessible to wildlife from the upland wildlife refuge area whereas the road blocks the wildlife corridor to Site B.

- Site A has more opportunity to support fish habitat than Site B because it is adjacent to fish habitat whereas Site B is not.
- Site A has more opportunity to improve water quality than Site B because of its proximity to the coast and because its longest dimension is parallel to the coast, therefore providing greater "buffering" potential.
- Site A is down-slope of agricultural land uses that generate harmful levels of nutrients that without a wetland at Site A would reach the water body.
- Site B, on the other hand, creates a narrow "buffer" away from the coast and has no significant upslope source of nutrients to filter.
- Even with a source of nutrients, the payoff from filtering nutrients at Site B would be less than at Site A because Site B is adjacent to a polluted and fast-moving section of the water body where harmful effects would be negligible.
- Site A is located where it provides aesthetic and educational opportunities to a nearby residential population whereas Site B is surrounded by industrial sites and private forest lands which limits its amenity values.

These differences indicate how landscape context can affect the relative value of wetlands even if they are identical in terms of site characteristics. It also illustrates the mitigation ratio's need to reflect location as well as time and risk.

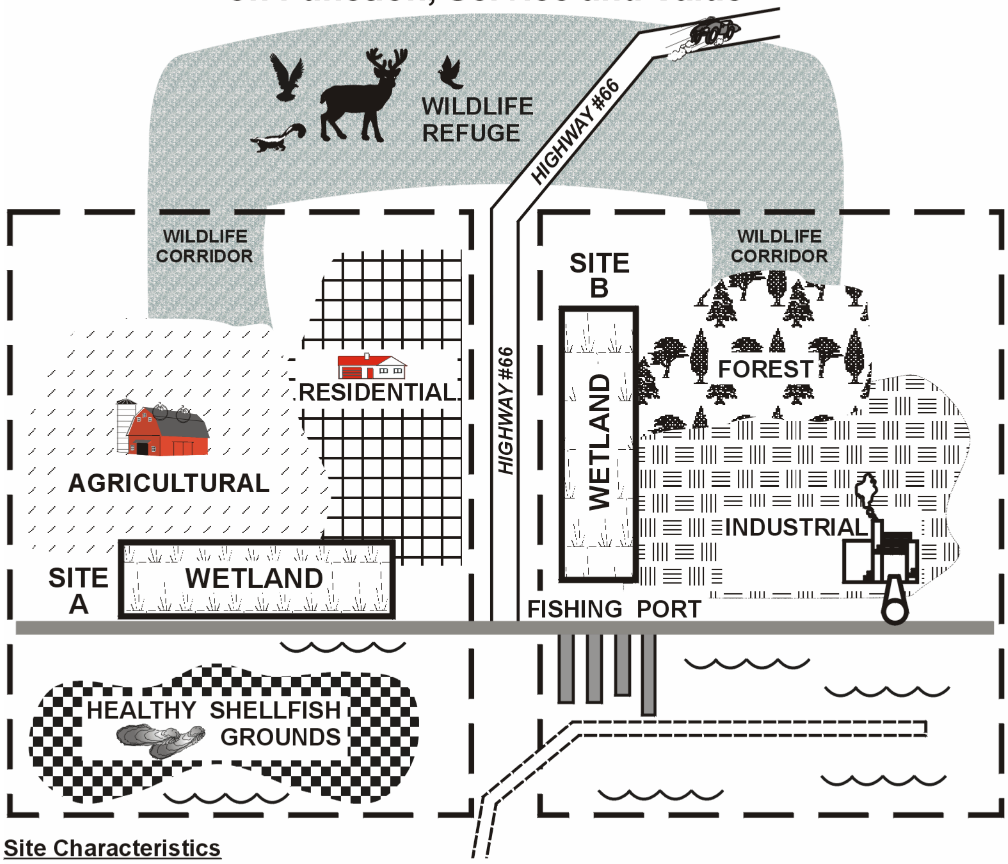
<u>Conclusions about Wetland Location</u>

The above illustration serves to demonstrate three points. First, wetland functional capacity is a necessary but not sufficient condition for wetland value; factors related to the landscape context limit or enhance the expected value of wetlands. Second, information about landscape context provides a logical and defensible basis for comparing relative (non-dollar) wetland values without resorting to complicated and controversial dollar-based valuation methods. Third, mitigation ratios that are intended to take account of differences in the value of wetlands gained and lost through offsite mitigation should take account of differences in wetland location.

Differences in landscape context measured at greater geographic scales, (e.g. different watersheds) can be expected to have similar effects. In fact, the greater the distance between the impacted wetland and the replacement wetland, the greater the potential for broad-scale and systemic differences in landscape conditions that could affect their relative value. This is particularly important when assessing the cumulative impacts of mitigation at the scale of a watershed or a water basin.

Figure C1

Effects of Wetland Location on Function, Service and Value



Site Characteristics

Wetland Site A and Wetland Site B are identical in size, shape and bio-physical characteristics and are located in the same sub-watershed on either side of Highway 66.

Landscape Context

SITE A

- near the coast, downstream is a beach area
- adjacent to large healthy shellfish grounds that are accessible to the community
- upslope is agricultural land (nutrient run off)
- wildlife corridor open from the North
- near residential areas (aesthetics, scenic)
- good access, adjacent public lands
- access to many urban poor people

SITE B

- slightly off coast, downstream is industrial site
- adjacent to fishing port and small shellfish beds that are contaminated and remote
- upslope is forest (no nutrient runoff)
- wildlife corridor is blocked by Highway 66
- nearby industrial sites (no proximity to people)
- poor access, surrounded by private lands
- access to few suburban rich people

APPENDIX D

List of Wetland Assessment Methods

Assessment Methods.

	Name	Acronym	Reference
1	Alberta Lentic	Alberta Lentic	Alberta Riparian Habitat Management Society 2003a, b, 2004a, b
2	Alberta Lotic	Alberta Lotic	Alberta Riparian Habitat Management Society 2003c, 2004c, d
3	Amphibian IBI	Amphibian IBI	Micacchion 2002
4	Avian Richness Evaluation Method	AREM	Adamus 1993a, b
5	Bay Area Watershed Science Approach	WSA	Watershed Science Team 1998
6	Bird Community Index	BCI	O'Connell et al. 1998, 2000
7	California Rapid Assessment Method	CRAM	Collins et al. 2004
8	Connecticut Method	Connecticut Method	Ammann et al. 1986
9	Coral Reef Assessment and Monitoring Program	CRAMP	Jokiel and Friedlander 2004
10	Delaware Method	DE Method	Jacobs 2003
11	Eeelgrass	Eelgrass	Short et al. 2000
12	Evaluation for Planned Wetlands	EPW	Bartoldus et al. 1994
13	Floristic Quality Assessment Index	FQAI	Andreas et al. 2004, Bernthal 2003, Herman et al. 2001, Lopez and Fennessy 2002, Mushet et al. 2002, NGPFQP 2001
14	Habitat Assessment Technique	HAT	Cable et al. 1989
15	Habitat Evaluation Procedure	HEP	USFWS 1980, 1981
16	Hollands-Magee Method	Hollands-Magee Method	Hollands and Magee 1985
17	Hydrogeomorphic Approach	HGM Approach	NRCS et al. 1995, Smith 1993, Smith et al. 1995, Whited 1997
		HGM Approach - AR	AR Multi-Agency Wetland Planning Team 2001
		HGM Approach – Deciduous Wetland Flats	Rheinhardt et al. 1995, Rheinhardt and Brinson 1997
		HGM Approach – Estuarine Fringe OR	Adamus 2004
		HGM Approach – Guidebook AK	Hall et al. 2003
		HGM Approach – PA	Wardrop et al. 1998

	Name	Acronym	Reference
		HGM Approach – Prairie Potholes	Whited et al. 2003
		HGM Approach – Riverine Guidebook	Brinson et al. 1995
		HGM Approach – Riverine impounding Willamette Valley, OR	Adamus 2001, Adamus and Field 2001
		HGM Approach – Riverine Coastal Plain, Chesapeake Bay	USACE 1995a
		HGM Approach – Riverine Western KY	Ainslie et al. 1999
		HGM Approach – Riverine/slope AK	Powell et al. 2003
		HGM Approach – Tidal Fringe Guidebook	Shafer and Yozzo 1998
18	Index of Biotic Integrity	IBI	Karr 1981, 1987, 1990
19	Indicator Value Assessment	IVA	Hruby 1995
20	Larson-Golet Method	Larson-Golet Method	Golet 1976, Golet and Davis 1982, Heeley and Motts 1976, Larson 1976, Wencek 1986
21	Maryland Department of the Environment Method	MDE Method	East 1995, Taylor et al. 1997
22	Methods for Assessing Wetland Functions	MAWF	Hruby and Granger 1996, Hruby et al.1997, 1999a, b, 2000a, b, 2004, WA State Dept Ecology 2002
23	Minnesota Routine Assessment Method	MIN RAM	MBWSR 2004
24	Montana Wetland Assessment Method	MT Form	Berglund 1999
25	New Hampshire Method	NH Method	Ammann and Stone 1991
26	New Jersey Freshwater Wetland Mitigation	NJ Freshwater Wetland Mitigation	Balzano et al. 2002
27	North Carolina Coastal Region Evaluation of Wetland Significance	NC-CREWS	Sutter et al. 1999
28	North Carolina Guidance for Rating Values of Wetlands	NC Method	NCDEHNR 1995
29	Ohio Rapid Assessment Method for Wetlands	ORAM	Mack 2001
30	Oregon Method	Oregon Method	Roth et al. 1993, 1996
31	Oregon Watershed Assessment Manual	OR Watershed Assessment Manual	OR Watershed Enhancement Board 1999
32	Oyster	Oyster	Coen and Luckenbach 2000

	Name	Acronym	Reference
33	Pennsylvania Habitat Evaluation Procedure	PAM HEP	Palmer et al. 1985, USFWS 1980
34	Process for assessing proper functioning condition	PFC	Clemmer 1994, Gebhardt et al. 1990, Leonard et al. 1992, Lewis et al. 2003, Myers 1989, Prichard 1993, Prichard et al. 1993, 1996, Sada et al. 2001
35	Process for assessing proper functioning condition	PFC – Lentic	Prichard et al. 1998b, 1999
36	Process for assessing proper functioning condition	PFC – Lotic	Prichard et al. 1998a
37	Salt marsh health	Salt marsh health	Pennings et al. 2002
38	Savannah District SOP	Savannah District SOP	USACE Savannah District. 2003
39	Synoptic Approach for Wetlands	Synoptic Approach	Abbruzzese et al 1990a, b, Abbruzzese and Leibowitz 1997, Hyman and Leibowitz 2000, Leibowitz et al. 1992, McAllister et al. 2000, Schweiger et al. 2002, Vellidis et al. 2003
40	TNC - Integrity Assessment and Ecological Models	TNC - Integrity Assessment	TNC 2003, 2004a, b
41	TNRCC Stream Habitat Assessment Procedure	TNRCC Stream Habitat Assessment Procedure	TNRCC 1999
42	Transport Suitability Index	TSI	Short and Davis 1999
43	Vegetation Index of Biotic Integrity	VIBI	Mack et al. 2000
44	VIMS Method	VIMS Method	Bradshaw 1991
45	WA State Wetland Rating System (Western)	WA State Wetland Rating System	WA State Dept Ecology 1993
46	Water Quality Index	WQI	Lodge et al. 1995
47	Wetland Evaluation Technique	WET2	Adamus et al. 1987, 1991
48	Wetland Functions and Values	Descriptive Approach	USACE 1995b
49	Wetland Habitat Indicators for Nongame Species	WEThings	Whitlock et al. 1994a, b
50	Wetland Habitat Indicators for Nongame Species	WEThings - Birds	Crowley et al. 1994, Crowley 1997
51	Wetland Rapid Assessment Methodology	WRAP	Miller and Gunsalus 1997
52	Wetland Value Assessment Methodology	WVA	EWG 2002
53	Wildlife Habitat Appraisal Procedure	WHAP	TPWD 1991
54	Wisconsin Rapid Assessment Methodology	WI RAM	WDNR 2001

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