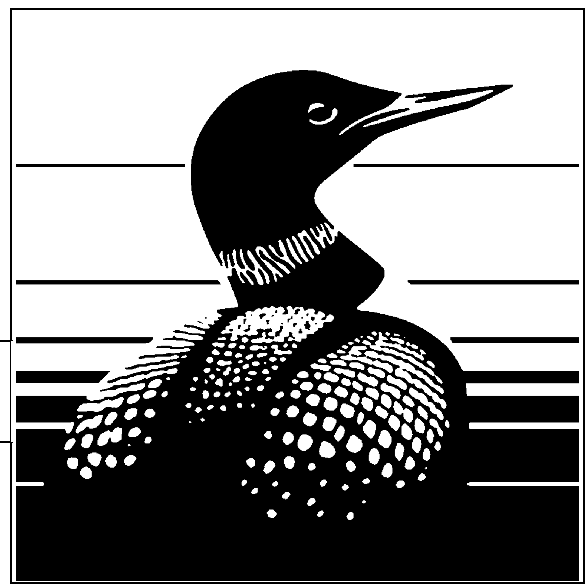
Wetland Ecological Functions Assessment: An Overview of Approaches

Al Hanson, Lee Swanson, Dave Ewing, Greg Grabas, Shawn Meyer, Lisette Ross, Mike Watmough, Jan Kirkby

Atlantic Region



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SUMMARY

In Canada, the Federal Policy on Wetland Conservation and many provincial wetland conservation policies have objectives of 'no net loss' of wetland function. A wetland functions assessment provides key information on wetlands that is important for environmental assessment of proposed projects. Quantitative assessment of wetland functions is critical for the successful implementation of the environmental assessment mitigation hierarchy of avoidance, minimisation, and compensation of impacts on wetlands from proposed projects.

It is important to distinguish between wetland function and wetland values. Wetland values reflect the ecosystem services that wetlands provide to humans and the societal values placed upon these services. Wetland ecological functions are the natural processes (physical, chemical, biological) that are associated with wetlands independent of considerations of the benefits of those processes to humans.

The wetland valuation process (Wetland Evaluation Guide) developed by Bond *et al*. (1992) serves a useful purpose in highlighting the need to consider wetland values in decisions regarding wetlands in Canada. However, many users of the Wetland Evaluation Guide complete only a checklist exercise instead of completing a detailed analysis of wetland values. The multiple wetland values evaluation matrix (Bond *et al*. 1992) was not intended to be used without supporting quantitative data, and cannot be used to determine potential impacts of a project on wetland functions and the effectiveness of impact minimisation and compensation actions.

During the last 20 years, approximately 100 different methods have been developed to assess wetland ecological functions. The purpose of this Technical Report is to provide an overview of

a) different approaches to conducting wetland ecological functions assessment,
b) recent reviews of assessment methods,
c) decision support tools for selecting wetland ecological functions assessment methods,
d) rapid assessment methods that have broad applicability to Canadian information needs,
e) links to more information.

Recent reviews of existing methods for assessing wetland ecological functions have indicated that no single method is best for all regions and situations in the United States or Canada. The applicability of any method must be based on wetland types and questions to be addressed by the wetland functions assessment. It is recommended that all current sources of information and expertise on wetland ecological functions assessment procedures be utilised during the evaluation process (*e.g.*, internet, primary literature, WetKit, government agencies). The use of any existing wetland ecological functions assessment method should be accompanied by a brief description of why that methodology was chosen. The plethora of existing methods to assess wetland ecological functions indicates that assessments in Canada should be based on established methods. Rapid assessment methods developed in the States of Ohio, Minnesota, Wisconsin, and Washington have great applicability to Canadian situations. These State methods provide the information we consider to be fundamental to any wetland ecological functions assessment conducted in Canada (Appendix A).

Future work and field testing in the United States and Canada will provide more guidance on how to select the best wetland ecological functions assessment procedure and continue to refine the scientific validity and cost-effectiveness of assessment methods.

RÉSUMÉ

Au Canada, la Politique fédérale sur la conservation des terres humides, comme bien des politiques provinciales de conservation des terres humides, a pour objectif de prévenir toute perte nette de fonctions des terres humides. L'évaluation des fonctions des terres humides permet de recueillir à ce sujet des renseignements fondamentaux, nécessaires à l'évaluation environnementale des projets proposés. L'évaluation quantitative des fonctions des terres humides est essentielle pour mettre en place la séquence hiérarchique de solutions d'atténuation : éviter, réduire au minimum et compenser les répercussions des projets proposés sur les terres humides.

Il est important de faire la distinction entre les fonctions et les valeurs des terres humides. Les valeurs représentent les services que les humains tirent des écosystèmes humides, ainsi que les valeurs que la société attribue à ces services. Quant aux fonctions écologiques, il s'agit des processus naturels (physiques, chimiques, biologiques) associés aux terres humides, indépendamment des avantages qu'en tirent les humains.

Le processus d'évaluation des terres humides (Guide d'évaluation des terres humides) élaboré par Bond *et al.* (1992) s'avère utile en ce qu'il souligne la nécessité de prendre en compte les valeurs rattachées aux terres humides dans les décisions qui concernent ce type de milieu au Canada. Cependant, de nombreux utilisateurs du Guide se bornent à remplir une liste de vérification au lieu de réaliser une analyse approfondie des valeurs des terres humides. La matrice d'évaluation des terres humides à valeurs multiples (Bond *et al.*, 1992) n'a jamais été prévue pour être utilisée sans données quantitatives à l'appui et ne peut servir à déterminer l'incidence potentielle d'un projet sur les fonctions des terres humides, ni l'efficacité des mesures de réduction et de compensation des effets.

Au cours des 20 dernières années, une centaine de méthodes d'évaluation des fonctions écologiques des terres humides ont vu le jour. Le présent Rapport technique vise à donner un aperçu des éléments suivants :

a) les différentes approches de l'évaluation des fonctions écologiques des terres humides,
b) les plus récents examens des méthodes d'évaluation,
c) les outils d'aide à la décision créés pour faciliter le choix de méthodes d'évaluation des fonctions écologiques des terres humides,
d) les méthodes d'évaluation rapide qui correspondent le mieux aux besoins d'information au Canada,
e) des liens vers de plus amples renseignements.

D'après des études récentes sur les méthodes actuelles d'évaluation des fonctions écologiques des terres humides, aucune méthode ne convient parfaitement à toutes les situations et toutes les régions des États-Unis ou du Canada. Tout dépend des types de terres humides et des questions auxquelles l'évaluation de leurs fonctions écologiques doit répondre. Dans le cadre du processus d'évaluation, on recommande d'avoir recours à l'expertise et à toutes les sources d'information à jour disponibles sur les méthodes d'évaluation des fonctions écologiques des terres humides (p. ex. Internet, documents primaires, WetKit, organismes gouvernementaux). L'utilisation d'une méthode d'évaluation existante doit toujours être brièvement justifiée. Il existe tellement de méthodes pour évaluer les fonctions écologiques des terres humides qu'il semble raisonnable d'employer des méthodes bien établies. D'ailleurs, les méthodes d'évaluation rapide élaborées en Ohio, au Minnesota, au Wisconsin et dans l'État de Washington semblent

convenir particulièrement aux situations canadiennes, puisqu'elles fournissent les renseignements que nous estimons fondamentaux dans toute évaluation des fonctions écologiques des terres humides réalisée au Canada (annexe A).

Les futurs travaux et essais sur le terrain effectués aux États-Unis et au Canada permettront de préciser davantage la façon de choisir la meilleure méthode d'évaluation des fonctions écologiques des terres humides, de renforcer la validité scientifique des méthodes d'évaluation et d'en améliorer le rapport coût-avantages.

1. INTRODUCTION

A common scientific and regulatory definition of a **wetland** is "*land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment"* (National Wetlands Working Group 1988). **Wetland ecological functions** are the natural processes (physical, chemical, biological) that are associated with wetlands independent of considerations of the benefits of those processes to humans (Government of Canada 1991, Milko 1998, Kusler 2004a,b). For the remainder of this document, wetland ecological functions will often be referred to simply as wetland functions.

Wetland values reflect the ecosystem services that wetlands provide to humans and the societal values placed upon these services. Wetland values are based on wetland ecological functions but the two are not synonymous. For any given wetland ecological function, associated wetland value may differ depending on individual or community preferences (Manuel 2003). An understanding of wetland value is an important consideration, and in some jurisdictions a mandated component, of environmental assessment (Milko 1998, Kusler 2004a). The focus of this Technical Report is to assess wetland ecological functions rather than assessing wetland values.

In Canada, the Federal Government, many provinces, territories and municipalities have developed policy and enacted legislation to protect wetland area and function (Farnese and Belcher 2006, Austen and Hanson 2007, Schulte-Hostedde *et al*. 2007, Rubec and Hanson 2009). The **Federal Policy on Wetland Conservation (FPWC**) states that the objective of the Federal Government with respect to wetland conservation is to: "promote the conservation of Canada's wetlands to sustain their ecological and socio-economic functions, now and in the future" (Government of Canada 1991). The FPWC and many provincial policies have a goal of 'no net loss' of wetland function (see review in Rubec and Hanson 2009) and are based on the mitigation sequence of avoidance, minimisation, and compensation of impacts on wetland function (Lynch-Stewart *et al.* 1996). With many wetland regulations and policies requiring compensatory mitigation for loss of wetland function, it is increasingly important that wetland functions be quantified for impacted wetlands as well as any wetlands that may be restored, enhanced or created (Austen and Hanson 2008). An understanding of wetland functions through a standardized quantitative assessment procedure is important for wetland restoration, enhancement, and acquisition programs as well as environmental assessments (Kusler 2006).

1.1. The Need to Assess Wetland Functions in Environmental Assessments

The FPWC is an important consideration in federal projects that are evaluated under the *Canadian Environmental Assessment Act*. An **environmental assessment (EA)** identifies possible environmental effects, proposes measures to avoid and mitigate adverse effects, and predicts whether there will be significant adverse environmental effects, even after the mitigation is implemented (Canadian Environmental Assessment Agency (CEAA) 2003). The two main purposes of EA are to avoid or minimize adverse environmental effects before they occur and incorporate environmental factors into decision making (CEAA 2003).

The Canadian Environmental Assessment Agency (CEAA) defines a **Valued Ecosystem Component (VEC)** as the environmental element of an ecosystem that is identified as having scientific, social, cultural, economic, historical, archaeological or aesthetic importance (CEAA 2006). The value of an ecosystem component may be determined on the basis of cultural ideals or scientific concern. CEAA (2006) recommends that valued ecosystem components that have the potential to interact with project components be included in the assessment of environmental effects. Wetlands are recognized as a Valued Ecosystem Component because of their important ecological functions and associated socio-economic values (Beanlands and Duinker 1983). It is therefore important that wetland functions be assessed during EA.

1.2. Goals of Wetland Functions Assessment

There is an abundance of proven wetland functions assessment methods, limiting the need to 'reinvent the wheel' (Fennessy *et al.* 2004, 2007). The first wetland assessment techniques developed were **wetland evaluation techniques** which combined an identification of wetland ecological functions with an analysis of wetland values (Bond *et al.* 1992, OMNR 2002). In the United States (US), the federal government and many State governments developed wetland evaluation techniques (Adamus *et al*. 1987). The goal of wetland evaluation techniques was not to quantitatively describe the wetland and associated functions, but rather to determine the relative ecosystem and societal importance of the wetland from the perspective of wetland and landscape conservation planning. The use of wetland evaluation techniques in the US has diminished over time because experience has shown the procedures to be complicated, time consuming and inadequate for evaluating impact reduction, compensation measures, or prescribing compensatory mitigation requirements for no net loss of function (Kusler 2004b). The Canadian experience with wetland valuation (Bond *et al.* 1992) highlights the same limitations as experienced in the US. In Canada, there has been the added problem that instead of completing a detailed analysis of wetland values as outlined in the multiple value evaluation matrix, oftentimes only a checklist exercise was completed without any empirical or quantitative justification.

In the US, many new wetland ecological functions assessment methods have been developed since wetland evaluation techniques were developed (*e.g.,* Sutula *et al.* 2006). Reviews of different methods have concluded that there is no single assessment method that best meets the needs of all situations in all geographic areas (Bartoldus 2000, Fennessy *et al.* 2004, Kusler 2006, Fennessy *et al.* 2007). However, there are many wetland assessment methods that can address common information needs such as those listed in Appendix A.

Wetlands are particularly dynamic ecosystems, and as such can be difficult to classify, quantify, and evaluate. For example, they are in transition between one ecosystem class and another (*e.g.*, bog→fen→swamp), and their functions are heavily influenced by factors such as hydrology, climate, natural disturbance, and human activity in and adjacent to wetlands. Wetland function can be difficult to measure and valuate, which can create challenges when economic valuation is required (Jacques Whitford Environmental Limited (JWEL) 2007). However, the fact that wetland ecosystems are dynamic and influenced by many factors does not constitute a reason to avoid assessment of wetland function. Rather, it underscores the need for clear criteria for wetland functions assessment and the use of field tested and established assessment methodologies.

1.3. Purpose of Document

In Canada, there has been confusion within the environmental consulting community on the differences between wetland ecological functions and wetland values. In some cases regulatory agencies have requested that a wetland functions assessment be completed but instead an analysis of wetland values has been performed. Completion of the checklist of the multiple wetland values evaluation matrix (Bond *et al.* 1992) without quantitative data is not recommended as a wetland functions assessment method in Canada.

This document provides an overview of the theory and practice of conducting wetland functions assessments primarily as they relate to EA. However, information on wetland functions assessment will be useful in relation to wetland conservation policies, wetland acquisition programs and wetland restoration projects. The intended audience for this document includes EA practitioners, environmental consultants, project proponents, land use planners and wetland managers.

The purposes of this document are to:

1) Highlight the differences between wetland ecological functions and wetland socio-economic values.
2) Discourage the use of Bond *et al.* (1992) as a method to assess wetland ecological functions.
3) Identify the information that should be provided by a wetland ecological functions assessment.
4) Provide an overview of the various wetland ecological functions assessment approaches that have been developed in the United States and Canada.
5) Identify previous reviews and decision support systems that have been developed in the United States and Canada to assist in selecting the most appropriate wetland ecological functions assessment method.
6) Provide links to information and tools that will facilitate the selection and use of established wetland ecological functions assessment methods in Canada.
7) Encourage the use of established methods to conduct wetland ecological functions assessments in Canada.
8) Initiate the development of approved (provincially, territorially, and federally) wetland ecological functions assessment methods in Canada.

2. WETLAND INFORMATION NEEDED FOR ENVIRONMENTAL ASSESSMENT (EA)

2.1. Best Practices for EA

Information on wetland functions is one of many types of information required for an EA of potential project impacts. Information on wetland values is also an important component of EA in many jurisdictions. Some of the major wetland ecological functions and associated wetland values are summarized in Table 1 (see Bond *et al*. 1992, North American Wetlands Conservation Council Canada (NAWCCC) and Environment Canada (EC) 2000, JWEL 2007).

Table 1. Examples of relationships between wetland functions and values.

Function Category	Functions	Key Values
Hydrology	Aquifer recharge and discharge Surface water storage and release Flow moderation	Replenishing groundwater supplies Moderation of stormwater peaks Climate moderation Maintenance of water flow during drought Reduced water velocity and removal of suspended sediments
Biochemical Cycling	Nutrient transformations Biomass production Soil production	Atmospheric carbon sequestration Natural water quality improvement Reduction in excess nutrients
Habitat	Biological productivity and diversity	Production of harvestable species (for food, fuel, peat production, etc.) Provision of biodiversity (genetic resources) Habitat for species at risk Erosion control and shoreline stabilization
Climate	Carbon fixation and CO_2 balance Methane equilibrium Rainfall and humidity increases Micro-climatic influences	Maintaining current climate for human activities and society

Information collected on wetlands should support the overall EA and adhere to best practices. The International Association for Impact Assessment has stated that EA should be: *Purposive, Rigorous, Practical, Relevant, Cost-effective, Efficient, Focused, Adaptive, Participative, Interdisciplinary, Credible*, *Integrated, Transparent* and *Systematic* (see Senecal *et al*. 1999 for further explanation).

Information on wetlands in the EA should allow for a determination of current baseline conditions, cumulative effects, functions of the wetland, potential impacts, and the effectiveness of the mitigation strategy of avoidance, minimisation, and compensation (Lynch-Stewart *et al.* 1996). Important guidance on wetlands and the CEAA has been produced (NAWCCC and EC 2000) and is summarized in Table 2. Recent academic reviews of the practice of EA in Canada provide useful information (Hanna 2005, Noble 2006).

Environment Canada previously identified the types of information and analyses regarding wetlands that it would expect to see in an EA (Milko 1998, NAWCCC and EC 2000). Some provinces have provided similar advice on their web sites and in written EA guidance documents (*e.g.,* www.gov.ns.ca/snsmr/paal/nse/paal586.aspreferences). Milko (1998) provided a conceptual approach and a list of important information requirements but did not provide any guidance on wetland functions assessment methodologies. In addition to the information needs listed in Milko (1998), it is equally important that an EA reflect the policy and regulatory requirements applicable to the jurisdiction where the project is proposed (see Rubec and Hanson 2009).

2.2. Sequence of Wetland Information Needs for EA

Kusler (2006) provided a chronological listing of what can be considered priority information needs of regulatory agencies. **Considerations for describing a wetland include starting with simple descriptors such as water sources, hydrology, and water budget, and progressing towards landscape level descriptors** (NAWCCC and EC 2000). These considerations are summarized below:

1) *Start with simple descriptors that are key determinants of wetland functions*
Are you dealing with a single wetland or a wetland complex? What is the class or type of wetland, size, shape (morphometry) and the position of the wetland(s) within the landscape? Provide maps showing these features and their relationship to the project components.

2) *Treat the wetland as a three-dimensional system*
What are the contours of the system – the depths of water and organic layers? What volume of water is it capable of storing? Cross-section diagrams may be helpful.

3) *Consider the wetland's hydrological regime*
What are the hydrological pathways and water budget of the wetland? Consider the sources and quantities of inflowing water (streams, sheet flow, melt water, groundwater and precipitation) and types of outflows (such as discharge into a watercourse, evapo-transpiration, percolation through the soil), and volumes of standing water. What are the input/output relations of water and other materials, including pollutants?

4) *Treat the wetland as a dynamic system*
What is the range of water level fluctuations over the course of a day, month, or through the seasons? What are the low and high-flow volumes and frequencies? Over the long-term, how is the water budget changing? Are there any other relevant changes that are occurring in soil structure, water chemistry, and biotic communities?

5) *Look at the wetland in a landscape context*
What is the surrounding land cover and land use? Describe the diversity of adjacent habitats. Consider the dependence of wetland wildlife on adjacent upland or deepwater habitats. Describe the proximity/linkages to other wetlands and natural habitats. What is the spatial distribution of other wetlands in the landscape? What are the historical patterns of development in the landscape and the resulting changes (cumulative effects) to wetlands?

Information on wetlands in the EA should allow for a determination of current baseline conditions, functions and values of the wetland and the effectiveness of the mitigation strategy of avoidance, minimisation, and compensation (Lynch-Stewart *et al.*1996). Listings of wetland functions and values (Appendix B) as well as mitigation measures (Appendices C, D, E) have been previously published (NAWCCC and EC 2000, Gabor *et al.* 2004, Kusler 2004a, JWEL 2007).

Table 2. Important elements of Environmental Assessments (EA) involving wetlands (adapted from NAWCCC and EC 2000).

In Advance
• Know the wetland "red flags". These are features of the wetland or surrounding landscape assigned special recognition or protection (*e.g.*, coastal wetlands, RAMSAR sites, critical habitat for 'listed' species). Red flags need to be determined at national, regional, provincial/territorial, and local levels. • Familiarize yourself with wetland tools and information sources.
General
• Determine whether wetlands are an issue early in project planning. • Engage the appropriate expertise at the beginning of a project and at every step in the EA process. • Engage stakeholders in an open approach emphasizing information sharing.
Scoping
• Determine if wetlands are in the area of influence of the project using existing information (wetland inventory and expert knowledge) and field data. • Identify wetland boundaries. Use applicable regulated delineation standards. • Determine if it is a regulated wetland pursuant to a particular policy, or regulation. • Determine if the proposed activity is a regulated or exempted activity. • Determine what permits are required. • Use existing information sources supplemented by site inspection. • Inquire if Environment Canada and provincial/territorial conservation agencies can provide wetland inventory data. • Identify wetlands as valued ecosystem components. • Identify alternatives to the proposed activity. • Adhere to mitigation sequence of avoidance, minimization, and compensation of impacts. • Determine the importance of the potential effects and the appropriate level of effort to put into the assessment of effects. Consider: Red Flags; context (especially past losses, rarity and wetland objectives); cumulative effects; wetland functions; size and nature of the project; anticipated scale; severity of the effects; and vulnerability of the wetland to project impacts.
Assessing Environmental Effects
• Focus the description of the wetland on its capacity to perform hydrological, water quality improvement, and habitat functions. • Describe those ecological components or attributes that are associated with wetland functions.

- Quantify functions wherever reasonable and possible.
- Focus the assessment of adverse effects on how a project's activities may alter the wetland ecosystem's capacity to perform hydrological, bio-chemical and habitat functions.
- Build on information gathered to assess functions of the wetland.
- Determine impacts by comparing actual functions (pre-project) with predicted functions (post-project).
- Determine and quantify the natural hazards at the site (*e.g.,* flooding).
- Determine and quantify if the proposed project activity will increase natural hazards at the site and on other adjacent lands (*e.g.,* flooding).
- Ensure that the proposed project complies with all applicable regulations.
- Determine the cumulative effects on the wetland.

Mitigating Environmental Effects

- Plan the best course of action for eliminating or reducing wetland function losses by following the mitigation sequence of: avoidance, minimization, and compensation.
- Focus mitigation objectives on functions.
- Key approach is avoidance of impacts and protection of wetlands if at all possible.
- If compensation is chosen as the preferred mitigation option, then a compensation strategy must be developed that includes the requisite elements for a successful wetland enhancement, restoration, or creation project.
- Consider that compensatory mitigation can be a time and money intensive undertaking, not to be entered into without due consideration.
- Consider that "Success" of compensation projects varies according to wetland type and region.

Determining Significance

- Determine whether effects on wetlands can be considered adverse. The FPWC indicates that effects on wetlands are adverse if they result in loss of wetland functions.
- Determine significance based on the functions assessment (which identifies change in wetland functions) <u>and</u> existing objectives, guidelines, standards, criteria and thresholds for wetland conservation at local, provincial/territorial, regional, national and international levels.
- Consider that wetland loss or degradation: can contribute to major or catastrophic events; has the potential for widespread effects; may be irreversible; and may be more serious in some geographic areas than others.

Follow-Up and Monitoring

- Monitor wetland functions in the short- and long-term to ensure that mitigation measures, including compensation, are successful, and contribute to adaptive management.
- Monitor wetlands as per legislative requirements (*e.g.*, SARA and CEAA).

3. IDENTIFYING WETLANDS

A fundamental question regarding wetlands within an EA is to determine whether a wetland is within a project's area of impact. Tools to provide this information include: wetland inventory, wetland delineation, wetland classification, and Geographic Information Systems (GIS). Because of the importance of these tools they are described in more detail below.

3.1. Wetland Inventory

Although Canada does not currently have a national wetland inventory (Fournier *et al.* 2007), there are regional and provincial wetland inventories (Lynch-Stewart and Rubec 1993; Hanson and Calkins 1996; Ingram *et al*. 2004; Létourneau and Jean 2005, 2006a, b, c; Grenier *et al*. 2007; Dahl and Watmough 2007; Hogg and Todd 2007). Many areas of the country were mapped as Phase 1 projects of the Canadian Wetland Inventory (Fournier *et al.* 2007). These inventories are often a valuable tool for a preliminary assessment of wetland distribution at the landscape level. Most wetland inventories in Canada are based on visible wetland characteristics such as vegetation and the presence of water. Therefore these inventories do not contain all wetlands especially those that are ephemeral, small and/or forested. **Wetland inventories and associated data should be considered as a starting point for wetland information and must be followed up by field based investigations.** Digital terrain models and related depth to water table mapping can be valuable tools in determining wetland presence (Hogg and Todd 2007, Murphy *et al.* 2007).

To find out more on the availability of wetland inventory information for a given area contact your regional Canadian Wildlife Service – Environment Canada office, as well as territorial/provincial natural resources or environment departments.

3.2. Wetland Identification and Delineation

Wetland identification and delineation involves a determination of whether a wetland exists and its spatial boundaries. Many jurisdictions in the United States and Canada have adopted the wetland delineation principles of the United States Army Corps of Engineers (US ACE). This system identifies wetlands based on a combination of soil, hydrology, and vegetation (US ACE 1987). Training courses on wetland delineation are offered throughout North America by a variety of academic institutions, environmental organizations, and companies. **Some jurisdictions in Canada have established guidelines and minimum standards for wetland delineation submissions** and requirements for the credentials of wetland delineators (*e.g.*, New Brunswick Department of the Environment (NB DENV) 2007).

3.3. Wetland Classification

For areas where wetland inventories exist, there will also be an accepted wetland classification methodology and terminology that should be used (Hanson and Calkins 1996, Albert *et al.* 2005, Murphy *et al*. 2007). It is important to use the accepted wetland classification system for the appropriate jurisdiction in order to improve consistency of information. Most jurisdictions in Canada use the Canadian Wetland Classification System (CWCS) as the basis for their classification system (Warner and Rubec 1997, National Wetland Working Group 1988). The CWCS recognizes five wetland classes: bog, fen, mars, swamp, and shallow water. There are also associated forms and subforms. In the southern regions of the western provinces, wetland classification systems by Stewart and Kantrud (1971) and Cowardin *et al.* (1979) are often used to identify wetlands. Information from these and other wetland inventories and classification systems can be cross-referenced to the CWCS (*e.g.*, Hanson and Calkins 1996, Lee *et al*. 1998, MacKenzie and Moran 2004, Dahl and Watmough 2007).

3.4. Mapping Wetland Information

To convey information about wetlands it is important to map spatially explicit data such as boundaries, vegetative community, open water, soils, and water depth. Equally important is mapping and recording information relating wetlands to other features in the landscape, such as topography, watercourses, lakes, other wetlands, adjacent habitat, and land use. Provincial and territorial air photos and orthophotos, satellite imagery, and mission specific air photos, can be good base maps onto which geo-referenced observations can be added using GIS.

Written guidance and field methods and workshops have been produced on Global Positioning Systems (GPS), wetland delineation and wetland mapping (*e.g.*, Southam and Curran 1996, NB DENV 2007).

4. WETLAND FUNCTIONS ASSESSMENT APPROACHES

This section provides a brief overview of some of the many methods that have been developed to assess wetland functions. Regardless of the method used, it is important that each provides basic information such as that listed in Appendix A.

4.1. Tiered Monitoring and Assessment Framework

In recent years, monitoring and assessment programs have been categorized using a three-tier system (Fennessy *et al*. 2004, Apfelbeck and Farris 2005, Neckles and Hanson 2005, Kentula 2007). This approach categorizes assessment and monitoring procedures into a hierarchy of three levels based on intensity and scale (not importance). These range from broad, landscape-scale assessments (known as Level 1 methods), rapid field methods (Level 2) to intensive biological and physical-chemical studies (Level 3). Each level can be used to validate and inform the others. For example, data collected with a rapid method can validate and refine remote sensing / landscape-level techniques. Biological assessments (Level 3) are often used to calibrate or validate rapid methods (Level 2) or better understand cause and environmental effect relationships. Rapid assessment methods hold a central position in monitoring programs because once established, they can provide sound, quantitative information on the status of the wetland resource with a relatively small investment of time and effort (Fennessy *et al*. 2007). The US Environmental Protection Agency (US EPA) and Wisconsin Department of Natural Resources (Wisconsin DNR) have recently endorsed the concept of the Level 1, 2, 3 approach to monitoring and assessing wetlands.

4.2. Level 1 – Landscape Level Assessments

Wetland assessments that consider the broader landscape (*e.g.,* sub-shed, watershed, county, or province) can help identify the relative importance of wetland functions within the landscape. Wetland inventory data can assess the relative abundance of wetlands in the landscape and some provide a description of the juxtaposition of each wetland in relation to other wetlands (Hanson and Calkins 1996). Wetland assessments at broad spatial scales can also highlight the importance of a given wetland to conserving specific wetland types. The FPWC and the New Brunswick Wetland Conservation Policy, for example, list salt marshes as wetland types that require specific conservation activities. Depending on the location, this landscape level wetland assessment may have already been completed or may simply require a quick assessment using GIS and existing data.

The US EPA developed a synoptic approach to wetland assessment, which evaluated overall landscape features and the wetland position in the landscape (Abbruzzese and Leibowitz 1997). This methodology does not evaluate individual wetlands; instead it emphasizes the importance of considering the relationship of the wetland to the landscape, and using GIS and the theories of landscape ecology in order to better understand wetland function (Schweiger *et al*. 2002).

4.3. Level 2 – Rapid Assessments

The proliferation of wetland assessment techniques has been primarily due to a desire for a quick, inexpensive technique. It should be noted when selecting a wetland functions assessment method that the terminology for methods is not standardized (*e.g.*, some methods termed ‘rapid’ may actually be very time consuming). Fennessy *et al*. (2004, 2007) defined rapid assessment methods as those that could be completed by two people in less than a half day in the field and a half day in the office doing preparation and data analysis. Experience in the US has shown that many of the rapid assessment techniques are neither quick nor inexpensive (Kusler 2006). Therefore it is important to use assessment techniques that suit the project’s needs and are appropriate to the region. Moreover, the simplifications and assumptions of some rapid assessment techniques may result in indicators that do not accurately reflect the functions in question. Consequently, some rapid assessment methods produced inaccurate results, or results that could have been more easily obtained with a field visit and a narrative description. To assist in selecting a rapid assessment method, the utility of various approaches are highlighted in this section and information reviews and selection procedures are provided in Sections 5 and 6.

Wetland Evaluation Techniques

As mentioned in Section 1.2, the first wetland assessment techniques developed were wetland evaluations, which combined an identification of wetland functions with an analysis of wetland services and benefits (Bond *et al*. 1992, OMNR 2002). Various jurisdictions in the US developed wetland evaluation techniques (Adamus *et al*. 1987). The use of wetland evaluation techniques in the United States has diminished over time because experience has shown the procedures to be complicated, time consuming, and inadequate for evaluating environmental impact reduction, compensation measures or prescribing compensatory mitigation requirements for no net loss of function (Kusler 2004b). Limitations of wetland evaluation techniques also included its heavy reliance on professional judgement and its mixing of issues related to wetland functions and wetland values.

The wetland valuation process developed by Bond *et al*. (1992) has the same limitations as other wetland evaluation techniques with the added problem that instead of completing a detailed analysis of wetland values, oftentimes only a checklist exercise is completed without any empirical or quantitative justification. The multiple wetland values evaluation matrix (Bond *et al*. 1992) was not intended to be used without supporting data. Consequently, **the wetland valuation process of Bond *et al*. (1992) is not recommended as a wetland ecological functions assessment method.** It is can however be a valuable tool in identifying wetland values associated with a given wetland if based on empirical data.

State Rapid Assessment Methods

In response to limitations of wetland evaluation techniques, some US jurisdictions have proposed the use of more robust and detailed wetland functions rapid assessment methods. All of these State methodologies have merit, and attempt to collect much of the same information but in slightly different ways reflecting State regulatory/policy nuance and wetland ecology. For example, Montana developed a rapid assessment method to be a first step field evaluation assessing wetland condition, potential stressors, and restorability (Apfelbeck and Farris 2005). However the assessment is not intended to give the user a quantitative or diagnostic analysis of wetland condition. Conversely, the California Rapid Assessment Method (Collins *et al.* 2007) obtains a lot of information on wetland condition but is more detailed than many would want in a rapid assessment methodology.

The types of information that should be collected by wetland functions rapid assessment methods are contained within Appendix A. While it is beyond the scope and purpose of this report to describe them all, the following State methods are highlighted because they collect much of the information outlined in Appendix A and therefore are good sources of guidance.

Minnesota Board of Water and Soil Resources (Minnesota BWSR) created the Minnesota Routine Assessment Method (MnRAM) for evaluating wetland functions (Minnesota BWSR 2007). The method fills the need for a practical assessment tool that helps local authorities make sound wetland management decisions.

Wisconsin Department of Natural Resources (Wisconsin DNR) published a “Rapid Assessment Methodology for Evaluating Wetland Function Values” that allows for a rapid visual assessment of many important wetland functions (Wisconsin DNR 2001). Much of the information requirements in Appendix A are derived from the Wisconsin assessment form.

The Ohio Environmental Protection Agency developed the Ohio Rapid Assessment Method (ORAM) to assess the condition of attributes in Ohio wetlands (Mack 2001). The conditions of wetland attributes are generally expressed as indices (*e.g.*, Index of Biotic Integrity) and include assessments of elements such as vegetation, amphibians, birds, and landscape development (Mack 2001).

Certain State rapid assessment methods may be more applicable to particular projects or locations in Canada. For example, the rapid assessment method developed for western Washington (Hruby 2004) and Massachusetts have elements that would be applicable to marine coastal wetlands in Canada.

Regardless of which wetland functions assessment method is used, it is imperative that a brief description of why that methodology was used also be included with the assessment.

The use of established wetland functions assessment protocols such as those developed by the States of Minnesota, Wisconsin, Ohio, and Washington offer a structured approach to collecting the information outlined in Appendix A.

4.4. Level 3 – Detailed Assessments

Kusler (2006) listed seven different groups of detailed assessment models:
1) detailed field observations;
2) hydrologic and hydraulic models;
3) stream hydrologic geomorphic stability;
4) Index of Biological Integrity (IBI);
5) wetland replacement evaluation procedure;
6) Hydrogeomorphic Approach (HGM);
7) area wide assessments.

The different assessments focus on different wetland functions or information needs and Kusler’s (2006) review of wetland functions assessment methodologies provides useful guidance on their use.

Further elaboration on the Index of Biotic Integrity (IBI), Great Lakes Coastal Wetland Assessments, and Hydrogeomorphic (HGM) approach are provided below because of their potential application to a wide range of projects across Canada.

Index of Biological Integrity (IBI)

The United States Environmental Protection Agency (US EPA) has created a series of reports on assessing wetland condition using IBIs for invertebrates, algae, nutrients, amphibians, birds, vegetation, land use, etc. (Table 3, US EPA 2002a). These methods have been termed bio-assessments due to their focus on biota. The modules provide information on study design (US EPA 2002b) as well as detailed information on sampling methods (US EPA 2002c) and are available on-line, as well as through WetKit (www.wetkit.net). The approaches and methods outlined by the US EPA have great applicability to the assessment of wetland biological functions in Canada.

Table 3. US EPA Modules for evaluating wetland condition.

Module Number and Name	
1	Introduction to Wetland Biological Assessment
2	Introduction to Wetland Nutrient Assessment
3	The State of Wetland Science
4	Study Design for Monitoring Wetlands
5	Administrative Framework for the Implementation of a Wetland Bioassessment Program
6	Developing Metrics and Indices of Biological Integrity
7	Wetlands Classification
8	Volunteers and Wetland Biomonitoring
9	Developing an Invertebrate Index of Biological Integrity for Wetlands
10	Using Vegetation to Assess Environmental Conditions in Wetlands
11	Using Algae to Assess Environmental Conditions in Wetlands
12	Using Amphibians in Bioassessments of Wetlands
13	Biological Assessment Methods for Birds
14	Wetland Bioassessment Case Studies
15	Bioassessment Methods for Fish
16	Vegetation-Based Indicators of Wetland Nutrient Enrichment
17	Land-Use Characterization for Nutrient and Sediment Risk Assessment
18	Biogeochemical Indicators
19	Nutrient Load Estimation
20	Sustainable Nutrient Loading

Great Lakes Coastal Wetland Assessments

The Great Lakes Coastal Wetlands Consortium (GLCWC) developed a framework to cost effectively implement rapid assessment techniques to assess and report on physical and biotic attributes of Great Lakes coastal wetlands, including water quality and fish, bird, amphibian, invertebrate, and vegetation communities (Burton *et al*. 2008).

In support of the GLCWC, Canadian Wildlife Service – Ontario co-led the development of a regional coastal wetland monitoring project on Lake Ontario (Environment Canada and Central Lake Ontario Conservation Authority 2004, 2005, 2007). It is recommended that future wetland functional assessments for Great Lakes coastal wetlands consider the methods developed for this monitoring project. Whereas datasets related to these projects are extensive and in some cases ongoing, additional field data collection may not be necessary for some Great Lakes coastal wetlands.

Hydrogeomorphic Approach (HGM)

The hydrogeomorphic (HGM) approach (Brinson *et al*. 1993) and associated methods (Smith *et al*. 1995) have been widely accepted as wetland functions assessment methods. The HGM methodology compares the characteristics of a study wetland with those of local reference wetlands in relation to hydrologic, biogeochemical and habitat functions at a watershed scale (Table 4). The characteristics of the wetlands evaluated are specific to the wetland type and region. To date over 16 guidebooks on the HGM approach have been produced (US ACE 2007, Appendix F). HGM functions and associated ecosystem services have been summarized by Kusler (2006) and Smith *et al*. (1995). Although the HGM approach was developed for use in the US, many of the regional guidebooks cover wetland types and ecoregions (*e.g.*, prairie potholes) that occur in Canada (Gilbert *et al*. 2006). The use of the HGM approach requires the existence of data on wetland function for reference wetlands, so currently it cannot be used for all wetland types/regions due to lack of existing data.

Table 4. HGM approach to wetland functions and values (adapted from Smith *et al.* 1995).

Functions Related to:	Benefits, Products, and Services
HYDROLOGIC PROCESSES	
Temporary Storage of Surface Water	Onsite: Replenish soil moisture, import/export materials, conduit for organisms. Offsite: Reduce downstream peak discharge and volume and help maintain or improve water quality.
Longer Term Storage of Surface Water	Onsite: Provide habitat and maintain physical and biogeochemical processes. Offsite: Reduce dissolved and particulate loading and help maintain and improve surface water quality.
Storage of Subsurface Water	Onsite: Maintain biogeochemical processes. Offsite: Recharge surficial aquifers and maintain base flow and seasonal flow in streams.
Moderation of Groundwater Flow or Discharge	Onsite: Maintain habitat. Offsite: Maintain groundwater storage, base flow, seasonal discharge flows, and surface water temperatures.

Dissipation of Energy: the reduction of energy in moving water at the land/water interface.	Onsite: Contribute to nutrient capital of ecosystem. Offsite: Reduce downstream particulate loading and help to maintain or improve surface water quality.
BIOGEOCHEMICAL PROCESSES	
Cycling of Nutrients: the conversion of elements from one form to another through abiotic and biotic processes.	Onsite: Contributes to nutrient capital of ecosystem. Offsite: Reduce downstream particulate loading and help maintain or improve surface water quality.
Removal of Elements and Compounds: the removal of nutrients, contaminants, or other elements and compounds on a short-term or long-term basis through burial, incorporation into biomass, or biochemical reactions.	Onsite: Contribute to nutrient capital of ecosystem, remove contaminants or render innocuous. Offsite: Reduce downstream loading and help to maintain or improve surface water quality.
Retention of Particulates: the retention of organic and inorganic particulates on a short-term or long-term basis through physical processes.	Onsite: Contributes to nutrient capital of ecosystem. Offsite: Reduce downstream particulate loading and help maintain or improve surface water quality.
Export of Organic Carbon: the export of dissolved or particulate organic carbon.	Onsite: Enhances decomposition and mobilization of metals. Offsite: Supports aquatic food webs and downstream biogeochemical processes.
WETLAND HABITAT	
Plant and Animal Communities: the maintenance of plant and animal community that is characteristic with respect to species composition, abundance, and age structure.	Onsite: Maintain habitat for plants and animals, (especially SAR), forest and agriculture products, and aesthetic, recreational, and educational opportunities. Offsite: Maintain corridors between habitat islands and landscape/regional biodiversity.

5. PREVIOUS REVIEWS OF METHODS

Wetland functions assessments attempt to describe the functions of a wetland in qualitative, semi-quantitative, and/or quantitative fashion. Over the last 20 years many methods have been developed. Herein, we do not reiterate the results from reviews of wetland functions assessment methods previously conducted (*e.g.*, Bartoldus 1999, 2000, Committee on Mitigating Wetland Loss 2001, Fennessy *et al*. 2004, 2007, Carletti *et al*. 2004, Kusler 2006). WetKit (www.wetkit.net) can assist in finding these documents and websites.

Bartoldus (1999) reviewed 40 different existing wetland assessment techniques and compared their relative strengths. **Bartoldus (2000) concluded that the various methods for assessing wetland function, wetland condition, and wetland values had relative merits and that there was no single method that was appropriate for all situations.** Furthermore the abundance of wetland assessment procedures made the process of selecting a procedure confusing and time consuming. A 10-step framework to assist in deciding among 39 assessment procedures was developed (Table 5). This framework is based on guidance available on the following websites:

- http://el.erdc.usace.army.mil/emrrp/emris/emrishelp6/the_process_of_selecting_a_wetland_assessment_procedure_steps_and_considerations.htm
- http://el.erdc.usace.army.mil/emrrp/emris/emrishelp6/wetland_procedure_descriptions.htm

Table 5. Summary of steps in selecting a wetland functions assessment procedure (after Bartoldus 2000).

Step	Description of Each Step
1a	Define goals of assessment.
1b	Identify general objectives/applications.
2	Select preferred procedure approach.
3	Select applicable geographic province or region (*e.g.*, Alberta or prairies).
4	Select general habitat types (*e.g.*, peatland or salt marsh).
5	Define the described level of detail and sensitivity while considering time, resources, and cost and then select the maximum time to be allotted for the assessment of each site.
6	Determine if there is a need to generate results that include the size of the habitat in the measure of the function (i.e., do you need to make a distinction between a 1 ha and 100 ha site with regard to function and size?).
7	Identify the desired function and value categories.
8	Determine whether you want a separate unit measure of each function and value category or a composite score.
9	Determine if there is a need to compare different habitat types and or habitats from different geographic regions and if so, identify procedures that will facilitate a comparison, or decide how comparisons can be made.
10	Determine whether the procedure can be used to meet the specific goals of the assessment.

Carletti *et al*. (2004) reviewed 17 methods, based on the number of functions, number of indicators, wetland of application, geographic scale, time and expertise needed, aims, results etc., for potential application to Mediterranean wetlands. They concluded that the modular approach of the Massachusetts Office of Coastal Zone Management (Carlisle *et al*. 1998) was the most promising method for their needs and potential use.

Kusler (2006) completed a similar analysis of wetland functions assessment methods to Bartoldus (2000) but noted that the number of existing methods had grown to over 100. Much of the proliferation in proposed methodologies could be attributed to the desire for a ‘silver bullet’ rapid assessment technique that would be applicable to all jurisdictions and situations. **Kusler (2006) concluded that there was no one method that could be applied ubiquitously and that the application of different techniques in different situations was justified if based on real distinctions in contextual needs and the capabilities of the different assessments**. To make better use of existing wetland functions assessment techniques, it is important to recognize that wetland decision makers require many types of information depending on the context and that a range of assessment methods and techniques are needed to provide this information (Table 6). Equally important Kusler (2006) noted that improved guidance on the use of particular techniques in specific circumstances was required. It is important to stress that the wetland functions assessment procedure selected must provide the jurisdictional information requirements (see Kusler 2004a, Kusler 2006).

Existing review documents should be considered prior to selecting a wetland functions assessment technique.

The method selected should provide the essential information identified in Appendix A.

Table 6. Recommendations for making better use of existing wetland functions assessment techniques (after Kusler 2006).

1	Recognize that decision-makers require many types of information, depending on the management tool and context, and that a range of assessment methods and techniques are needed to provide that information.
2	Recognize that decision-making information gathering and analysis needs are not confined to assessment of wetland functions or conditions.
3	Recognize that different jurisdictions have wetland regulations with specific information needs.
4	Make better use of existing sources of information and expertise.
5	Conduct field verification of wetland functions assessment methods.
6	Prepare improved guidance for the use of particular techniques in specific circumstances.
7	Broadly distribute guidance on the use of techniques.
8	Better train government agencies, consultants and others in the selection and use of various techniques.
9	Acknowledge limitations of assessment methods and reflect uncertainties and margins of error in continued alternative analysis requirements and mitigation ratios.
10	Develop a preliminary assessment process to help select appropriate assessment technique for use in specific circumstances.

6. DECISION SUPPORT SYSTEMS FOR SELECTION OF ASSESSMENT METHOD

To further facilitate the selection of wetland functions assessment methods, the Centre for Biological Informatics of the United States Geological Survey and George Mason University have created an Ecological Assessment Methods Database that lists and compares many different ecological functions assessment methodologies (http://assessmentmethods.nbii.gov/). In addition to comparing the various approaches, the web site allows for a search of approaches based on: method type, purpose, input data, basis for defining unit of analysis, and output type. The US EPA has also established a web site offering many technical documents on assessment of wetland condition (www.epa.gov/owow/wetlands/monitor/#meth).

Method selection tools, including the ecological assessments database and web-site, should be used to assist in the process of selecting the appropriate wetland functions assessment method.

7. CONCLUSIONS AND RECOMMENDATIONS

Experience and opinion in Canada and the United States indicate that no single wetland functions assessment technique can serve the needs of all regulatory agencies, regions, wetland types or situations (Kusler 2006). However, there are numerous methodologies that offer a structured approach to obtain the quantitative and qualitative information required to understand the potential impacts of a proposed project or activity on wetland function and determine compensatory mitigation requirements.

As indicated previously, the use of wetland evaluation techniques that rely mainly on qualitative information or professional opinion (*e.g.*, Adamus 1987, Bond *et al*. 1992) are no longer recommended as wetland functions assessment procedures.

Established wetland functions assessment protocols offer recognized approaches to conducting wetland functions assessments. Those developed by the States of Minnesota (Minnesota BWSR 2007), Wisconsin (Wisconsin DNR 2001), Ohio (Mack 2001), and Washington (Hruby 2004) should have great utility in Canada. Certain State rapid assessment methods may be more applicable to particular projects or locations in Canada. The use of any existing wetland functions assessment method should be accompanied by a brief description of the rationale for choosing that particular methodology.

US EPA methods for assessing wetland condition (*e.g.*, US EPA 2002a) and the HGM approach (*e.g.*, Gilbert *et al*. 2006) provide information on methods for assessing wetland functions and also provide guidance on data collection protocols.

The applicability of any method must be based on an evaluation of the wetland types and the questions to be addressed by the wetland functions assessment. It is recommended that all current sources of information and expertise on wetland functions assessment procedures (*e.g.*, internet, primary literature, WetKit, government agencies) be utilised during the evaluation process. The use of any existing wetland functions assessment method should be accompanied by a brief description of why that methodology was used.

Future work and field testing in the United States and Canada will provide more guidance on how to select the most appropriate wetland functions assessment procedure.

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Appendix A

Information that should be included in an assessment of wetland functions. Adapted from Wisconsin Rapid Assessment Methodology.

GENERAL INFORMATION

Project Name:

Project Proponent:

Evaluator(s), Affiliation and Contact Information:

Date(s) and Duration of Site Visit(s):

Description of seasonal limitations of inspection:
(*e.g.*, hydrologic and climatologic conditions, after heavy rains, presence of snow or ice cover, during drought year, during spring flood, during bird migration, before/after growing season)

Detailed Wetland Functions Assessment Method(s) Used and Why:

Name of Wetland:

Owners:
Is any part of the wetland in public, Aboriginal or conservation ownership? If so name:

Location: County, ¼ Section, Township, Parish, Range.
Property Identification Data
Geographic Coordinates
National Topographic Series 1:50,000 Map Sheet
Wetland Identifier, Wetland Map Sheet
Air Photo Number and Year (Attached)

Is the wetland part of a monitoring or research project where relevant data exists?

WETLAND DESCRIPTION

Wetlands Class based on Published Inventory:
Based on various inventory sources such as national (Canadian Wetland inventory), regional (Maritime Wetland Inventory), provincial (Prince Edward Island), municipal (Saint John):

Wetland Class (subclasses, types) based on Field Work:
Based on Canadian Wetland Classification System and/or regional, provincial or territorial classification system:

Size of wetland:

To nearest 0.1 ha as reported in wetland inventory and/or estimated using aerial photographs, and/or delineated in the field.

SITE DESCRIPTION

I. HYDROLOGIC SETTING

A. Describe the geomorphology of the wetland:
- Depressional (includes slopes, potholes, small lakes, kettles, etc.)
- Riverine
- Lake Fringe
- Extensive Peatland
- Coastal Marine
- Other
- Extensive Peatland

B. **Y N** Has the wetland hydrology been altered by ditching, tiles, dams, culverts, well pumping, diversion of surface flow, dikes, water control structures, beaver activity, industrial effluent additions or changes to runoff within the watershed? Circle those that apply and provide narrative details.

C. **Y N** Does the wetland have an inlet, outlet, or both (circle those that apply)? Include these features on site map.

D. **Y N** Is there any field evidence of wetland hydrology such as buttressed tree trunks, adventitious roots, drift lines, water marks, water stained leaves, soil mottling/reduced matrix, organic soils layer, or oxidized rhizospheres (circle those that apply)?

E. **Y N** Does the wetland have standing water, and if so what is the approximate depth (cm)? Provide a map / GPS coordinates of where water depth measurements were recorded. Approximately how much of the wetland has surface water (*e.g.*, percentage)

F. How is the hydroperiod (seasonal water level pattern) of the wetland classified?
- Permanently Flooded
- Seasonally Flooded (*e.g.*, spring freshet, snowmelt,)
- Ephemeral Vernal Pools, Sheetwater
- Saturated Soils (surface water seldom present)
- Tidal
- Artificially Flooded
- Artificially Drained

G. **Y N** Is the wetland a navigable body of water or is a portion of the wetland below the ordinary highwater mark of a navigable water body?

Identify and list any surface waters associated with the wetland or in proximity to the wetland (note approximate distance from the wetland and navigability determination).

Note if there is a surface water connection to other wetlands.

II. VEGETATION

A. Identify the vegetation communities present. Identify dominant plant species. Attach a list of plant species present. If applicable identify wetland indicator status of each plant species.

1. Floating leaved community dominated by:
2. Submerged aquatic community dominated by:
3. Emergent community dominated by:
4. Shrub community dominated by:
5. Deciduous broad-leaved tree community dominated by:
6. Coniferous tree community dominated by:
7. Open sphagnum mat or bog:
8. Sedge meadow / wet prairie community dominated by:
9. Other (explain):

B. List other plant species identified during site visit:

C. Identify any plant 'species or communities of special status' that have the potential to occur on or near the site, and identify the source of this listing and information:

D. Identify any plant 'species or communities of special status' that were observed in the field:

III. SOILS

A. Identify Federal or Provincial soil map used, soil association or soil series:

B. Field description:
Identify and describe soil sampling locations. Indicate dominant surface vegetation and landscape position at each location. Attach site maps showing sampling locations and GPS coordinates.

1. Organic soil? **Y N**
2. Indicate depth of organic layer (cm):
3. von Post scale:
4. Indicate: Fibrisol / Mesisol / Humisol
5. Marl present? **Y N**
6. Mineral soil present ? **Y N**
7. Circle all those present: mottles, reduced matrix, iron / manganese concretions, organic streaking
8. Depth of mottling within mineral surface if present (cm):
9. Munsell color of matrix and mottles:
10. Depth of reduced matrix within mineral surface if present (cm):
11. Munsell color of reduced matrix:
12. Depth of A Horizon:
13. Soil classification according to the Canadian System of Soil Classification (indicate Soil Order, Soil, Great Group, Soil Subgroup):

IV. ANTHROPOGENIC IMPACTS ON WETLAND

A. Is the wetland itself relatively free of obvious human influences (current and historical), such as:

1. **Y N** Buildings?
2. **Y N** Roads?
3. **Y N** Other structures?
4. **Y N** Trash?
5. **Y N** Pollution?
6. **Y N** Filling?
7. **Y N** Dredging/draining?
8. **Y N** Domination by non-native vegetation?
9. **Y N** Farming and Agriculture?
10. **Y N** Forestry?
11. **Y N** Mining / Resource Extraction?

V. SURROUNDING LAND USES AND VEGETATIVE COMMUNITIES

A. What is the estimated area of the wetland catchment (watershed) in ha?

B. In measured area (ha) or estimated as percentage of catchment (watershed) provide detail and describe the surrounding land uses, such as:

1. Developed (Industrial/Commercial/Residential)
2. Agricultural/cropland
3. Agricultural/grazing
4. Forested
5. Grassland
6. Grassed recreation areas/parks
7. Old field
8. Oil and gas
9. Highways or roads
10. Other (specify)

C. Describe the regulated buffer area (if applicable) immediately adjacent to the wetland (*e.g.,* disturbance, vegetation, erosion):

VI. SITE MAPS

A. If applicable attach the wetland delineation report including dates and delineator name(s) as per jurisdictional standards.

B. Provide information on wetland location in watershed, surrounding land use, special features at 1:50,000 scale.

C. Provide wetland map using several maps and/or different data layers if necessary. Map to scale, using GIS or hand drawn. Also include file with GPS coordinates of data.

Include on Map:

1. All sampling locations
2. Location of permanent photo stations
3. Spatial extent of this assessment
4. Project footprint and impact locations
5. Property boundaries
6. Wetland boundary
7. Inflow(s) /outflow(s)
8. Depth to water table (if available)
9. Vegetative communities
10. Wetland subclasses
11. Legend with north arrow, scale, etc

VII. FIELD BASED OBLIQUE PHOTOS

Provide digital photos with GPS coordinates and direction of photos and date

VIII. WETLAND FUNCTIONS PRESENT

The following requires the assessor to examine site conditions that provide evidence that a given function or value is present/absent and to assess the significance of the wetland to perform those functions. Narrative and quantitative justifications should be provided as appropriate. Positive answers to questions indicate the presence of factors important for the function. The questions are not definitive or all-inclusive, and are only provided to guide the assessment.

A) Special Features and “Red Flags”

1). Is the wetland in or adjacent to an area of special natural resource interest?
Answer “YES” or “NO”. For all “YES” answers provide details.
Examples:

- Salmonid streams, their tributaries, and lakes (cold water communities)
- Provincial, territorial, or federal designated wild and scenic rivers
- Designated riverway
- Designated scenic urban waterway
- Environmentally sensitive area or environmental corridor identified in an area-wide water quality management plan, special area management plan, special wetland inventory study, or an advanced delineation and identification study.
- Calcareous fen
- Park, forest, trail or recreation area
- Fish and wildlife refuges and fish and wildlife management areas
- Designated wilderness area
- Designated wetland (*e.g.*, Ramsar, WHSRN)
- Wilderness area
- Lands acquired for wildlife conservation (*e.g.*, North American Waterfowl Management Plan)
- Designated or dedicated natural area, (*e.g.*, NB Protected Natural Area)
- Surface water/Ground water identified or designated as an important source of water

2). **Y N** According to the Conservation Data Centre, federal / provincial / territorial data and expertise, local Environmental Non-Government Agencies, naturalists or direct observations, are there any rare, endangered, threatened, or special concern species in, near, or using the wetland or adjacent lands? If so, list the species of concern.

B) Vegetation Diversity

1. **Y N** Does the wetland support a variety of native plant species or is it dominated by a limited number of species?

2. **Y N Unknown** Is the wetland plant community regionally scarce or rare?

3. **Y N** Are there exotic species present (*e.g.*, reed canary grass, flowering rush, buckthorn, purple loosestrife)? Provide location (GPS or map) and amount (*e.g.*, number of plants or m^2).

C) Wildlife and Fish Habitat

1. List species of fish and wildlife observed, evidenced, or expected, to utilize the wetland:

2. **Y N** Does the wetland contain a number of major vegetative cover types? If so, is there a high degree of interspersion of those vegetation types? **Y N**

3. **Y N** Is the estimated ratio of open water to vegetative cover between 30 and 70 %? What is the estimated percentage?

4. **Y N Unknown** Does the surrounding upland habitat support a variety of wildlife species?

5. **Y N** Is the wetland part of or associated with a wildlife corridor or designated environmental corridor?

6. **Y N** Is the surrounding habitat and/or the wetland itself a large tract of undeveloped land important for wildlife that require large home ranges (*e.g.*, bear, woodland passerines)?

7. **Y N** Is the surrounding habitat and/or the wetland itself a relatively large tract of undeveloped land within an urbanized environment that is important for wildlife?

8. **Y N** Are there other wetland areas near the subject wetland that may be important to wildlife?

9. **Y N** Is the wetland contiguous with a permanent waterbody or periodically inundated for sufficient periods of time to provide spawning/nursery habitat for fish?

10. **Y N** Can the wetland provide significant food base for fish and wildlife (*e.g.*, insects, crustaceans, voles, forage fish, amphibians, reptiles, shrews, wild rice, wild celery, duckweed, pondweeds, watermeal, bulrushes, bur reeds, arrowhead, smartweeds, millets)?

11. **Y N** Is the wetland in or near any urban centers?

12. **Y N** Is the wetland located in a priority watershed/township as identified in Habitat Joint Ventures Plans of the North American Waterfowl Management Plan or Bird Conservation Region Plans?

13. **Y N** Is the wetland providing habitat that is scarce to the region?

D) Flood and Stormwater Storage/Attenuation

1. **Y N** Are there steep slopes, large impervious areas, moderate slopes with row cropping, or areas with severe overgrazing within the watershed (circle those that apply)?

2. **Y N** Does the wetland significantly reduce run-off velocity due to its size, configuration, braided flow patterns, or vegetation type and density?

3. **Y N** Does the wetland show evidence of flashy water level responses to storm events (*e.g.*, debris marks, erosion lines, stormwater inputs, channelized inflow)?

4. **Y N** Is there a natural feature or human-made structure impeding drainage from the wetland that causes backwater conditions?

5. **Y N** Considering the size of the wetland area in relation to the size of its watershed, at any time during the year is water likely to reach the wetland's storage capacity (i.e., the level of easily observable wetland vegetation)? In cases where greater documentation is required, one should determine the wetland's capacity to hold 25% of the run-off from a 1 in 100 year, 24 hour storm event.

6. **Y N** Considering the location of the wetland in relation to the associated surface water watershed, is the wetland important for attenuating or storing flood, or stormwater peaks, or spring snowmelt events (i.e., is the wetland located in the mid or lower reaches of the watershed)?

E) Water Quality Protection

1. **Y N** Does the wetland receive overland flow or direct discharge of stormwater as a primary source of water (circle that which applies)?

2. **Y N** Do the surrounding land uses have the potential to deliver significant nutrient and/or sediment loads to the wetland?

3. **Y N** Based on the answers to the flood/stormwater section above, does the wetland perform significant flood/stormwater attenuation (residence time to allow settling)? If yes, more quantitative details are required.

4. **Y N** Does the wetland have significant vegetative density to decrease water energy and allow settling of suspended materials?

5. **Y N** Is the position of the wetland in the landscape such that run-off is held or filtered before entering a surface water?

6. **Y N** Are algal blooms, extensive macrophyte growth, or other signs of excess nutrient loading to the wetland apparent (or historically reported)?

F) Shoreline Protection

1. **Y N** Is the wetland in a lake fringe, riverine or coastal setting?

If YES to above question, then answer the following questions.

2. **Y N** Is the shoreline exposed to constant wave action caused by long wind fetch or boat traffic?

3. **Y N** Is the shoreline and shallow littoral zone vegetated with submerged or emergent vegetation in the swash zone that decrease wave energy or perennial wetland species that form dense root mats and/or species that have strong stems that are resistant to erosive forces?

4. **Y N** Is the stream bank prone to erosion due to unstable soils, land uses, or ice floes?

5. **Y N** Is the stream bank vegetated with densely rooted shrubs that provide upper bank stability?

G) Groundwater Recharge and Discharge

1. **Y N** Related to discharge, are there observable (or reported) springs located in the wetland, physical indicators of springs such as marl soil, or vegetation indicators such as watercress or marsh marigold present that tend to indicate the presence of groundwater springs?

2. **Y N** Related to discharge, may the wetland contribute to the maintenance of base flow in a stream?

3. **Y N** Related to recharge, is the wetland located on or near a groundwater divide (*e.g.* an elevational highpoint)?

Appendix B

Summary of functions and values of different wetland types (adapted from JWEL 2007).

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
BOG – Hydrological Functions			
Water Flow Moderation (flood protection)	Capacity is related to volume difference between the maximum high-water and normal water level in wetland and size of the wetland compared to size of watershed. Value of function increases with increasing downstream at-risk infrastructure.	Applies generally to all subforms.	Generally low performance. Bogs are typically isolated from surface water inputs. Studies find that headwater wetlands increase the immediate response of rivers to rainfall because saturated soils convey rainfall rapidly.
Groundwater Recharge	Variable and difficult to quantify. Depends on basin shape, location within the watershed, substrate, local groundwater gradients, etc.	Bogs in permafrost regions, riparian, floating, shore, and slope.	Performance is low. Bogs in permafrost regions provide little opportunity for groundwater recharge. Riparian, shore and slope bogs may be located in areas of groundwater discharge. Floating bogs have no potential to directly recharge groundwater.
		Mound, dome, plateau, collapse, or scar.	Variable performance expected. Areas of groundwater recharge and discharge may be located in a single bog. Recharge may occur at the bog perimeter, or within the bog where underlying soils are permeable and the flow gradient is towards groundwater. Bogs located in topographic highs with thin peat deposits may have a higher probability of performance compared to bogs in low-lying areas.
Shoreline and Erosion Protection	Presence/absence of wetland in shoreline area. Erodibility of terrestrial region inland of wetland is related to composition of substrate and energy of adjacent water body. Value related to adjacent terrestrial land use.	Applies generally to all subforms.	Generally low performance, unless in coastal areas. Bogs are typically present in low energy environments where erosion is not expected to be significant.
Climate Regulation	May be related to evapo-transpiration rates and the size of the wetland.	Applies generally to all subforms.	Generally low performance. Bog communities have adapted to retain surface water, are perched above local water tables and may be associated with low evapotranspiration rates.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
BOG – Biogeochemical Functions			
Water Quality Treatment	Physical, chemical and biological water quality treatment is a function of the constituents of concern, the loading rates, water balance and hydroperiod, the substrate and vegetation assemblages. The performance can be estimated through chemistry monitoring and water budget estimates. The value is related to the sensitivity or use of receiving waters.	Applies generally to all subforms.	Generally low performance. Bogs are typically isolated from surface water inputs.
Nutrient and Organic Export	Export of nutrients and organic carbon to streams can increase primary productivity and subsequently the aquatic food chain. Peat lands and swamps are known to contribute to metabolism in stream ecosystems in this way; however, the internal dynamics are complex and not well understood.	Applies generally to all subforms.	Potentially high performance. Soluble, partially decomposed organic matter and associated nutrients produced in pore waters are flushed to down gradient water bodies during precipitation and high water events. May be a sink for nutrients (low export).
Carbon Sequestration and Storage	The key attributes are the volume and degree of decomposition (humification) of peat, and volume of woody and ericaceous biomass. Carbon balance studies of wetland types in various climates may provide estimates of uptake; carbon uptake rates are highly variable within and between wetlands.	Applies generally to all subforms.	Potentially high performance. Atmospheric carbon is stored in peat and woody biomass on the order of decades to millennia. Moderately decomposed sphagnum peat with buried woody remains offers high potential for release of carbon if the wetland is disturbed or altered.
BOG – Habitat Functions			
Biological Productivity and Support for Biodiversity	Presence or absence of significant species, and abundance of significant species. Significant species include species at risk, species related to recreation or subsistence, and commercially valued species.	Applies generally to all subforms.	Potentially high performance. Assessment requires site specific evaluation of the presence and abundance of locally valued species. Sources may include local museums, interviews with relevant stakeholders, site visits, local and provincial / territorial rare species databases, research documents, etc.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
FEN – Hydrological Functions			
Water Flow Moderation Services (flood and storm protection)	Capacity is related to volume difference between the maximum high-water and normal water level in wetland and size of the wetland compared to size of watershed. Value of function increases with increasing downstream at risk infrastructure.	Applies generally to all subforms.	Moderate performance. Small water table fluctuation provides some opportunity for additional storm flow storage; however, performance is seasonal and variable depending on morphology and placement within the watershed.
Groundwater Recharge	Variable and difficult to quantify, and depends on basin shape, location within the watershed, substrate, local groundwater gradients, etc.	Applies generally to all subforms.	Variable to low performance expected. Highly decomposed gramminoid peat provides an impermeable layer to vertical flow. Recharge may occur at the margins of the peat.
Shoreline and Erosion Protection	Presence/absence of wetland in shoreline area. Erodability of terrestrial region inland of wetland is related to composition of substrate and energy of adjacent water body. Value related to the use of terrestrial land adjacent to wetland.	Applies generally to all subforms.	Variable performance. Fens are typically present in low energy environments where erosion is not expected to be significant. Assessment requires site specific evaluation.
Climate Regulation	Will be related to evapotranspiration rates and the size of the wetland.	Applies generally to all subforms.	Potentially moderate performance. A mix of emergent herbaceous plants and shrubs may be associated with moderate rates of evapotranspiration.
FEN – Biogeochemical Functions			
Water Quality Treatment	Physical, chemical and biological water quality treatment is a function of the constituents of concern, the loading rates, water balance and hydroperiod, the substrate and vegetation assemblages. The performance can be estimated through chemistry monitoring and water budget estimates. The value is related to the sensitivity or use of receiving waters.	Applies generally to all subforms.	Potentially high performance due to a combination of physical processes, high interaction between water and root-bacteria assemblages, flow through substrate, and heterogeneity in oxidation. Performance is largely dependent on loading rates and the particular constituents of concern. Generalizations are not possible.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
Nutrient and Organic Export	Export of nutrients and organic carbon to streams can fuel bacteria and subsequently the aquatic food chain. Peat lands and swamps are known to contribute to metabolism in stream ecosystems in this way; however, the internal dynamics are complex and not well understood.	Applies generally to all subforms.	Potentially high performance. Soluble, partially decomposed organic matter and associated nutrients produced in pore waters are flushed to down gradient water bodies during precipitation and high water events. May be a sink for nutrients (low export).
Carbon Sequestration and Storage	The key attributes are the volume and degree of decomposition (humification) of peat, and volume of woody and ericaceous biomass. Carbon balance studies of wetland types in various climates may provide estimates of uptake; carbon uptake rates are highly variable within and between wetlands.	Applies generally to all subforms.	Potentially high performance. Atmospheric carbon is stored in peat and woody biomass on the order of decades to millennia. Highly decomposed peat and the general lack of trees suggest lower carbon storage than the bog form.
FEN – Habitat Functions			
Biological Productivity and Support for Biodiversity	Presence or absence of significant species, and abundance of significant species. Significant species include species at risk, species related to recreation or subsistence, and commercially valued species.	Applies generally to all subforms.	Potentially high performance. Assessment requires site specific evaluation of the presence and abundance of locally valued species. Sources may include local museums, interviews with relevant stakeholders, site visits, local and provincial / territorial rare species databases, research documents, etc.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
MARSH – Hydrological Functions			
Water Flow Moderation Services (flood and storm protection)	Capacity is related to volume difference between the maximum high-water and normal water level in wetland and size of the wetland compared to size of watershed. Value of function increases with increasing downstream at-risk infrastructure.	Tidal, estuarine, riparian, lacustrine, slope	Low to high performance. Marshes adjacent to watercourses, lakes and the ocean generally derive water from flood events in that body of water rather than from landscape runoff inputs. Riparian and floodplain marshes may provide significant storm water retention if there is a significant area of marsh present on the watercourse.
		Basin, hummock, spring.	Potentially high performance. Fluctuations in water level and the size of the wetland provide an indication of the capacity for the wetland to store storm flow. Marshes located high in the watershed, up-gradient of developed areas can be expected to provide significant storm flow moderation services.
Groundwater Recharge	Variable and difficult to quantify, and depends on basin shape, location within the watershed, substrate, local groundwater gradients, etc.	Tidal, estuarine, riparian, spring, lacustrine, slope, some basin marshes.	Low performance expected. Fringe marshes located adjacent to water bodies are likely to have upward gradients in subsurface water. Wetlands located in topographic lows are typically sites of groundwater discharge. Recharge may occur in seasonal dry periods.
		Basin, hummock marshes.	Moderate to variable performance expected. Basins are typically areas of groundwater discharge; however, marshes located in prairie potholes, craters, cirques and vernal pools have demonstrated groundwater recharge potential. Marshes located in topographic highs may raise local water tables through recharge.
Shoreline and Erosion Protection	Presence/absence of wetland in shoreline area. Erodability of terrestrial region inland of wetland is related to composition of substrate and energy of adjacent water body. Value related to the use of terrestrial land adjacent to wetland.	Tidal, riparian, lacustrine, estuarine.	Potentially high performance. Tidal marshes and riparian marshes adjacent to channels, floodplains, lakes and rivers are particularly important for capturing and depositing sediment (land creation), dissipating high-energy flows and waves, and maintaining cohesion of shoreline materials. Other marsh sub-forms have variable roles in shoreline and erosion protection.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
Climate Regulation	May be related to evapotranspiration rates and the size of the wetland.	Applies generally to all subforms.	Potentially high performance. Dense communities of herbaceous plant species adapted to fluctuating water tables may be associated with high rates of evapotranspiration.
Water Quality Treatment	Physical, chemical and biological water quality treatment is a function of the constituents of concern, the loading rates, water balance and hydroperiod, the substrate and vegetation assemblages. The performance can be estimated through chemistry monitoring and water budget estimates. The value is related to the sensitivity or use of receiving waters.	Applies generally to all subforms.	Potentially high performance due to a combination of physical processes, high interaction between water and root-bacteria assemblages, flow through substrate, and heterogeneity in oxidation. Performance may be estimated through inflow and outflow constituent monitoring, taking into account dilution, storm events discharges, and seasonal vegetation die off. Performance is largely dependent on loading rates and the particular constituents of concern. Generalizations are not possible.
MARSH – Biogeochemical Functions			
Nutrient and Organic Export	Export of nutrients and organic carbon to streams can fuel bacteria and subsequently the aquatic food chain. Marshes are known to contribute to metabolism in stream ecosystems in this way; however, the internal dynamics are complex and not well understood.	Applies generally to all subforms.	Variable performance. Actual performance due to a combination of both physical processes, high interaction between water and root-bacteria assemblages, flow through substrate, and heterogeneity in oxidation. These wetlands may mitigate upstream nutrient inputs, resulting in a net sink. Performance may be estimated through inflow and outflow constituent monitoring, taking into account dilution, storm events discharges, and seasonal vegetation die off.
Carbon Sequestration and Storage	The key attributes are the volume and degree of decomposition (humification) of peat, and volume of woody and ericaceous biomass. Carbon balance studies of wetland types in various climates may provide estimates of uptake; carbon uptake rates are highly variable within and between wetlands.	Tidal, lacustrine, and riparian marshes.	Moderate performance. Fluctuating water levels allow soil oxidation and release of stored carbon. High productivity of biomass provides significant sequestration of atmospheric carbon; however, rates of decomposition and metabolism are high and, thus, on an annual basis sequestration can be variable.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
Carbon Sequestration and Storage	The key attributes are the volume and degree of decomposition (humification) of peat, and volume of woody and ericaceous biomass. Carbon balance studies of wetland types in various climates may provide estimates of uptake; carbon uptake rates are highly variable within and between wetlands.	Riparian, basin, hummock, lacustrine, spring, and slope marshes.	Moderate to high performance. Under persistent inundation organic soils may accumulate. Vegetation productivity in rich conditions may be greater than decomposition in persistent anaerobic conditions.
MARSH – Habitat Functions			
Biological Productivity and Support for Biodiversity	Presence or absence of significant species, and abundance of significant species. Significant species include species at risk, species related to recreation or subsistence, and commercially valued species.	Applies generally to all subforms.	Performance is highly variable, but can be very high. Does not fit into a categorical framework of function. Assessment requires site specific evaluation of the presence and abundance of locally valued species. Sources may include local museums, interviews with relevant stakeholders, site visits, local and provincial / territorial rare species databases, research documents, etc.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
SWAMP – Hydrological Functions			
Water Flow Moderation Services (flood and storm protection)	Capacity is related to volume difference between the maximum high-water and normal water level in wetland and size of the wetland compared to size of watershed. Value of function increases with increasing downstream at risk infrastructure.	Discharge swamp, mineral rise swamp, raised peatland, slope swamp, tidal swamp.	Generally low performance. The typical topography and watershed position of these wetlands suggest that they have little capacity to capture and store storm water.
		Riparian flat swamp, inland swamp.	Potentially high performance. Treed riparian areas with a full understory act to capture flood waters, slow velocities and store flood water on the order of days to weeks, depending on the size, morphology and location within the watershed. The location of the swamp at the bottom of a watershed or on the shore of a large water body suggests that any storm flow moderation services would be insignificant in the context of the watershed size of the receiving body. Flat swamps are generally fed by surface runoff and experience water level fluctuations, indicating a capacity during low water periods to accommodate additional storm water inputs.
SWAMP – Hydrological Functions			
Groundwater Recharge	Variable and difficult to quantify, and depends on basin shape, location within the watershed, substrate, local groundwater gradients, etc.	Discharge, riparian, tidal, inland salt swamp or slope swamp.	Generally low performance. The typical hydrology giving rise to these systems suggests that groundwater recharge potential is low.
		Raised peatland, flat or mineral-rise swamp.	Unknown potential for performance. Depends on site specific morphology, substrate, and location within the watershed flow system.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
Shoreline and Erosion Protection	Presence/absence of wetland in shoreline area. Erodability of terrestrial region inland of wetland is related to composition of substrate and energy of adjacent water body. Value related to the use of terrestrial land adjacent to wetland.	Riparian and tidal swamps.	Potentially high performance. Tidal swamps and those riparian swamps adjacent to channels, floodplains, lakes and rivers are particularly important for capturing and depositing sediment (land creation), dissipating high-energy flows and waves, and maintaining cohesion of shoreline materials. Other swamp sub-forms have variable roles in shoreline and erosion protection in comparison to terrestrial and engineered systems, depending on site specific conditions.
Climate Regulation	May be related to evapotranspiration rates and the size of the wetland.	Applies generally to all subforms.	Potentially moderate performance. A mix of emergent herbaceous plants and shrubs may be associated with moderate rates of evapotranspiration.
SWAMP – Biogeochemical Functions			
Water Quality Treatment	Physical, chemical and biological water quality treatment is a function of the constituents of concern, the loading rates, water balance and hydroperiod, the substrate and vegetation assemblages. The performance can be estimated through chemistry monitoring and water budget estimates. The value is related to the sensitivity or use of receiving waters.	Applies generally to all subforms.	Potentially high performance due to a combination of physical processes, high interaction between water and root-bacteria assemblages, flow through substrate, and heterogeneity in oxidation. Performance may be estimated through inflow and outflow constituent monitoring, taking into account dilution, storm events discharges, and seasonal vegetation die off. Performance is largely dependent on loading rates and the particular constituents of concern. Generalizations are not possible.
Nutrient and Organic Export	Export of nutrients and organic carbon to streams can fuel bacteria and subsequently the aquatic food chain. Peat lands and swamps are known to contribute to metabolism in stream ecosystems in this way; however, the internal dynamics are complex and not well understood.	Applies generally to all subforms.	Variable performance. Actual performance due to a combination of physical processes, high interaction between water and root-bacteria assemblages, flow through substrate, and heterogeneity in oxidation. These wetlands may mitigate upstream nutrient inputs, resulting in a net sink. Performance may be estimated through inflow and outflow constituent monitoring, taking into account dilution, storm events discharges, and seasonal vegetation die off.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
Carbon Sequestration and Storage	The key attributes are the volume and degree of decomposition (humification) of peat, and volume of woody and ericaceous biomass. Carbon balance studies of wetland types in various climates may provide estimates of uptake; carbon uptake rates are highly variable within and between wetlands.	Applies generally to all subforms.	Moderate to high performance. Decomposed peat and woody surface vegetation store atmospheric carbon on the order of years to centuries. Seasonal cycles of fluctuating water table allow biomass and soil decomposition; however, high biomass productivity due to rich soils and porewater may offset decomposition in some swamps.
SWAMP – Habitat Functions			
Biological Productivity and Support for Biodiversity	Presence or absence of significant species, and abundance of significant species. Significant species include species at risk, species related to recreation or subsistence, and commercially valued species.	Applies generally to all subforms.	Performance is highly variable, and does not fit into a categorical framework of function. Assessment requires site specific evaluation of the presence and abundance of locally valued species. Sources may include local museums, interviews with relevant stakeholders, site visits, local and provincial / territorial rare species databases, research documents, etc.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
SHALLOW WATER – Hydrological Functions			
Water Flow Moderation Services (flood and storm protection)	Capacity is related to volume difference between the maximum high-water and normal water level in wetland and size of the wetland compared to size of watershed. Value of function increases with increasing downstream at risk infrastructure.	Basin.	Potentially high performance. Fluctuations in water level and the size of the wetland provide an indication of the capacity for the wetland to store storm flow. The location of the shallow water wetland at the bottom of a watershed suggests that any storm flow moderation services would be insignificant in the context of the watershed size of the receiving body.
		Tidal, estuarine, lacustrine, riparian.	Generally low performance. Shallow water wetlands without basin morphology have a low probability of collecting and retaining significant amounts of storm flow from the adjacent landscape. The location of the wetland at the bottom of a watershed or on the shore of a large water body suggests that any storm flow moderation services would be insignificant in the context of the watershed size of the receiving body.
Groundwater Recharge	Variable and difficult to quantify, and depends on basin shape, location within the watershed, substrate, local groundwater gradients, etc.	Applies generally to all subforms.	Unknown potential for performance. Depends on site specific conditions.
Shoreline and Erosion Protection	Presence/absence of wetland in shoreline area. Erodability of terrestrial region inland of wetland is related to composition of substrate and energy of adjacent water body. Value related to the use of terrestrial land adjacent to wetland.	Estuarine, lacustrine and riparian.	Potentially moderate performance. Submerged vegetation may contribute to dissipating and buffering high energy flows and wave activity prior to entering adjacent emergent wetland system.
		Basin.	Generally low performance. Basin form shallow water wetlands are not typically in a position in the landscape to provide shoreline and erosion protection.
Climate Regulation	May be related to evapotranspiration rates and the size of the wetland.	Applies generally to all subforms.	Potentially moderate performance. Standing open water and a mix of emergent and submergent plant species may be associated with moderate rates of evapotranspiration.

Value	Attributes	Wetland Sub-Forms	Probable Performance of Service
SHALLOW WATER – Biogeochemical Functions			
Water Quality Treatment	Physical, chemical and biological water quality treatment is a function of the constituents of concern, the loading rates, water balance and hydroperiod, the substrate and vegetation assemblages. The performance can be estimated through chemistry monitoring and water budget estimates. The value is related to the sensitivity or use of receiving waters.	Applies generally to all subforms.	Potentially high performance due to settling, photo-degradation and aeration. Performance is largely dependent on loading rates and constituents of concern. May be estimated through inflow and outflow constituent monitoring, taking into account dilution and seasonal events such as water column turnover and vegetation die off.
Nutrient and Organic Export	Export of nutrients and organic carbon to streams can fuel bacteria and subsequently the aquatic food chain. Peat lands and swamps are known to contribute to metabolism in stream ecosystems in this way; however, the internal dynamics are complex and not well understood.	Applies generally to all subforms.	Generally low performance. Labile organic matter and nutrients released from root exudates and the decomposition of biomass are circulated and used within the water column.
Carbon Sequestration and Storage	The key attributes are the volume and degree of decomposition (humification) of peat, and volume of woody and ericaceous biomass. Carbon balance studies of wetland types in various climates may provide estimates of uptake; carbon uptake rates are highly variable within and between wetlands.	Applies generally to all subforms.	Variable performance. Significant seasonal productivity of biomass results in seasonal uptake. Rates of decomposition and metabolism are high and, thus, on an annual basis sequestration is typically low.
SHALLOW WATER – Habitat Functions			
Biological Productivity and Support for Biodiversity	Presence or absence of significant species, and abundance of significant species. Significant species include species at risk, species related to recreation or subsistence, and commercially valued species.	Applies generally to all subforms.	Performance is highly variable, and does not fit into a categorical framework of function. Assessment requires site specific evaluation of the presence and abundance of locally valued species. Sources may include local museums, interviews with relevant stakeholders, site visits, local and provincial / territorial rare species databases, etc.

Appendix C

Potential impacts on wetland habitat, potential effects, and suggested mitigation. Adapted from NAWCCC and EC 2000).

Potential Habitat Impact	**Potential Effects**	**Suggested Mitigation**
Enrichment and Organic Loading	• Short-term: increases productivity • Long-term: encourages invasive species; decreases species richness; diminishes wetland structural diversity; decreases production; and succession in upland vegetation	• Monitor water quality and enforce water quality standards • Control timing and application of inputs (*e.g.*, fertilizers) • Encourage land stabilization techniques (*e.g.*, grazing, reseeding, and planting) • Create a constructed treatment wetland pre-discharge • Remove invasive/undesirable species • Introduce nitrogen fixing plants
Contamination	• Increases risk to all wetland dependant species • Impairs all wetland functions	• Monitor water quality and enforce water quality standards • Control timing and application of inputs (*e.g.*, fertilizers) • Encourage best management practices (*e.g.*, cropping, grazing, shore stabilization, oil/water separators) • Introduce plants that are contaminant-tolerant • Eliminate the use of pesticides and other contaminants on-site, and encourage integrated pest management • Provide appropriate contaminant storage and handling facilities (*e.g.*, a water tight service pit for vehicles)
Anthropogenic Acidification	• Reduces native diversity and production	• Monitor water quality and enforce water quality standards • Avoid areas susceptible to acidification (*e.g.,* waterlogged soils high in pyrite and organic matter) • Treat high pH waters prior to discharge (*e.g.*, application of lime) • Introduce plants that survive in low pH conditions

Potential Habitat Impact	Potential Effects	Suggested Mitigation
Anthropogenic Salinization	• Diminishes species richness	• Leach salts by flushing soils periodically • Introduce plants that are salt tolerant
Sedimentation and Soil Compaction	• Diminishes species richness • Increases habitat area in deep waters • Decreases habitat area in shallow waters	• Include suspended solids in water quality standards and monitoring • Control land use around affected area(s) to encourage stable, permanent land cover • Limit excavation and fill, dispose fill off-site • Encourage reforestation and/or soil conservation activities on upland areas • Require storm water management and/or sediment control practices (*e.g.*, sedimentation ponds, catch basins, oil/water separators, silt fences), and if necessary, the hydraulic removal of sediments • Construct walkways to concentrate pedestrian traffic • Cut openings in dense cattail stands to facilitate water flow and storage • Limit the timing of construction activities (*e.g.*, frozen ground conditions only) • Restrict accessible areas (avoid sensitive and highly erodible areas) and vehicle types (*e.g.*, use only low impact equipment)
Turbidity and Shading	• Diminishes habitat suitability • Reduces habitat productivity	• Require storm water management and/or sediment control practices (*e.g.*, sedimentation ponds, catch basins, oil/water separators, silt fences, etc.)
Vegetation Removal	• Reduces habitat availability and suitability (*e.g.*, nesting habitat) • Increases erosion potential • Encourages establishment of invasive species	• Limit affected areas and compensate for functions lost (*e.g.*, establish protected wildlife habitat areas) • Re-vegetate nearby areas with species high in wildlife value (food and habitat) • Provide nesting structures, logs, and/or rock piles for use as loafing sites by wildlife • Remove invasive species

Potential Habitat Impact	Potential Effects	Suggested Mitigation
Temperature Increase	• Reduces species richness	• Limit destruction of bank and existing streamside vegetation • Ensure water discharge is <3°C different than the receiving water body • Plant trees and shrubs for shade • Establish buffer of shade trees/shrubs along drainage pathways and water storage areas
Water Drainage	• Encourages invasion of undesirable species • Short-term: reinvigorates nutrient cycling • Long-term: converts to upland habitat	• Regulate/manage water levels (*e.g.*, via water level control structures to replicate natural flooding cycle) • Remove invasive/undesirable species.
Flooding	• Increases and/or decreases habitat space depending on species • Facilitates dispersal of isolated aquatic populations • Increases bank erosion • Dilutes contaminants, suspended sediment, and plant material • Introduces nutrients from newly flooded areas • Changes vegetative community over long-term	• Regulate/manage water flow (*e.g.*, install a water level control structure) • Avoid alteration/destruction of upstream wetlands that store large water volumes • Ensure adequate upland buffers are maintained to provide refuge habitat
Fragmentation	• Reduces biodiversity	• Involve natural resource agencies in the review of site location alternatives • Avoid or minimize disturbance of significant wetland areas • Identify 'at risk' populations (*e.g.*, endangered species) in site vicinity and protect their habitat(s) and corridors • Construct wildlife bridges/crossings, and maintain habitat corridors • Compensate for loss of functions (*e.g.*, high risk, ecologically sensitive areas in same watershed, possibly adjacent to an existing protected area). • Secure adjacent habitats

Appendix D

Potential impacts on wetland hydrology, potential effects, and suggested mitigation. Adapted from NAWCCC and EC 2000.

Potential Hydrological Impact	Potential Effects	Suggested Mitigation
Sedimentation and Soil Compaction	• Reduces storage, infiltration and groundwater recharge • Increases surface runoff • Decreases surface water storage and release	• Minimize compacted areas (*e.g.*, traffic flow) • Restrict access to specialized, low-impact equipment • Encourage revegetation and/or soil conservation activities along shoreline and upland areas • Require storm water management and/or sediment control practices (*e.g.*, sedimentation ponds, catch basins, oil/water separators, silt fences). If necessary, physical removal of sediment • Install water control structures (*e.g.*, logs) to reduce water flow speed
Vegetation Removal	• Reduces the interception, condensation, evaporation, and surface roughness (runoff resistance) • Increases runoff velocity and groundwater discharge	• Limit affected areas, especially along drainage pathways • Require sediment and water flow control structures/practices • Encourage reforestation and/or soil conservation activities on upland areas
Water drainage	• Reduces groundwater recharge potential • Increases evapotranspiration	• Maintain water flow (*e.g.*, volume and velocity) through project site (*e.g.*, via proper culvert sizing and installation) • Install water flow control structures
Flooding	• Increases infiltration and recharge of wetlands • Converts nearby wetlands from recharge to discharge areas (or vice versa)	• Create an overflow basin to prevent flooding downstream • Protect upstream wetlands and floodplains
Fragmentation	• Reduces groundwater recharge and discharge to remaining wetlands	• Involve natural resource agencies in the review of site location alternatives • Compensate for loss of wetland function by protecting similar functions within the same watersheds

Appendix E

Potential impacts on wetland limnology, potential effects, and suggested mitigation. Adapted from NAWCCC and EC 2000.

Potential Limnological Impact	Potential Effects	Suggested Mitigation
Enrichment	• Increases denitrification rate • Increases sediment stabilization • Increases biological uptake and processing • If extreme or chronic, may depress all of the above	• Monitor water quality and enforce water quality standards • Maintain buffer around all watercourses, wetlands, and sensitive areas • Control timing and application of inputs (*e.g.*, fertilizers) • Remove invasive/undesirable species • Create a constructed treatment wetland, pre-discharge
Organic Loading	• Enhances mobilization of some substances through oxidation effects • High loadings: reduces biological uptake and processing • Moderate loadings: increases denitrification rates and sedimentation	• Monitor water quality and enforce water quality standards • Maintain buffer around all watercourses, wetlands, and sensitive areas • Control timing and application of inputs (*e.g.*, fertilizers). • Remove invasive/undesirable species. • Create a constructed treatment wetland, pre-discharge.
Contamination	• Depresses denitrification, biological uptake/processing, and photosynthesis	• Monitor water quality and enforce water quality standards • Eliminate the use of pesticides and other contaminants on-site, and encourage integrated pest management • Provide adequate space and facilities for waste disposal • Provide appropriate contaminant storage and handling facilities • Require a spill mitigation plan and all necessary equipment on-site

Potential Limnological Impact	Potential Effects	Suggested Mitigation
Anthropogenic Acidification	• Reduces denitrification, biological uptake and processing, and photosynthesis • Increases mobility of heavy metals • Effects on chemical adsorption depend on chemical	• Monitor water quality and enforce water quality standards • Avoid areas susceptible to acidification (*e.g.*, waterlogged soils high in pyrite and organic matter) • Treat low pH waters prior to discharge (*e.g.*, application of lime) • Introduce plants that survive in low pH conditions
Anthropogenic Salinization	• Reduces denitrification, biological uptake, and photosynthesis • Enhances adsorption of some chemicals	• Leach salts by flushing soils periodically • Establish plants that are salt tolerant
Sedimentation and Soil Compaction	• Depresses biological uptake, processing, and photosynthesis • Reduces hydrologic residence time	• Avoid projects near important wetlands (*e.g.*, a provincially significant wetland) • Restrict accessible areas (*e.g.*, avoid sensitive and highly erodible areas) and vehicle types (use low impact equipment) • Construct walkways to concentrate pedestrian traffic • Control land uses around affected area(s) to encourage stable, permanent land cover • Restrict the timing of construction activities (*e.g.*, to avoid fish spawning seasons) • Limit excavation and fill, dispose off-site • Require reforestation and/or soil conservation activities on upland areas • Require the hydraulic removal of sediment
Turbidity and Shading	• Reduces photo-oxidation of some contaminants • Depresses denitrification, photosynthesis, and biological uptake	• Establish and maintain a buffer around all watercourses, wetlands, and sensitive areas • Armor stream crossings with stones or rip rap to prevent damage • Slow or divert sediment-laden discharges with straw bales

Potential Limnological Impact	Potential Effects	Suggested Mitigation
Vegetation Removal	• Reduces sedimentation • Reduces sediment stabilization • Reduces photosynthesis • Reduces biological uptake and processing • Reduces denitrification • Increases sediment removal capacity of early successional forested wetlands	• Ensure the project is not close to ecologically sensitive/important areas. • Involve natural resource agencies in the review of site location alternatives
Temperature Increase	• Increases rates of chemical and biological functions	• Monitor discharge temperature (ensure < 3^{o}C difference between discharge and receiving waters) • Include water temperature in water quality standards • Establish buffer of shade trees/shrubs along drainage pathways and water storage areas
Water Drainage	• Increase concentration of inorganic chemicals • Remobilizes many substances, especially organics and phosphorus • May renew wetland adsorption capacity for some substances	• Maintain water quality using bridges for stream crossings, vegetated buffers, and maintaining natural channel characteristics • Install water flow control structures
Flooding	• Increase sedimentation • Decrease biological uptake and processing • Decreases rate of photosynthesis	• Install water flow control structures • Create an overflow basin to prevent flooding downstream
Fragmentation	• Increases in distance between wetlands could reduce the effectiveness of coupled functions important to water quality	• Avoid or minimize disturbing wetlands critical to water quality improvement • Compensate for loss of wetland function by protecting similar functions within the same watershed

Appendix F

Documents on hydrogeomorphic approach to wetland functions assessments.

Classification:
The hydrogeomorphic classification of wetlands is intended to lay a foundation for and support ongoing efforts to develop methods for assessing the physical, chemical, and biological functions of wetlands.

Brinson, M. M. 1993. "A hydrogeomorphic classification for wetlands," Technical Report WRP-DE-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A270 053.

Approach:
The approach includes a development and an application phase. The assessment procedure, as the final product, can be used to compare project alternatives, determine impacts, calculate mitigation requirements, etc.

Smith, D. R., A. Ammann, C. Bartoldus and M. M. Brinson. 1995. "An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices," Technical Report WRP-DE-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A307 121.

National Guidebooks:
National Guidebooks are intended as general reviews of concepts and literature, and as templates for development of Regional Guidebooks.

Riverine:
Brinson, M. M., F. R. Hauer, L. C. Lee, W. L. Nutter, R. D. Rheinhardt, R. D. Smith and D. Whigham. 1995. "A guidebook for application of hydrogeomorphic assessments to riverine wetlands," Technical Report WRP-DE-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A308 365.

Tidal Fringe:
Shafer, D. J. and D. J. Yozzo. 1998. "National guidebook for application of hydrogeomorphic assessment of tidal fringe wetlands," Technical Report WRP-DE-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Guidelines for Developing Regional Guidebooks:

Clairain, E. J., Jr. 2002. "Hydrogeomorphic approach to assessing wetland functions: guidelines for developing regional guidebooks; Chapter 1, Introduction and overview of the hydrogeomorphic approach," ERDC/EL TR-02-3, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Smith, R. D. 2001. "Hydrogeomorphic Approach to Assessing Wetland Functions: Guidelines for Developing Regional Guidebooks - Chapter 3 Developing a Reference Wetland System," ERDC/EL TR-01-29, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Smith, R. D. and J. S. Wakeley. 2001. "Hydrogeomorphic Approach to Assessing Wetland Functions: Guidelines for Developing Regional Guidebooks - Chapter 4 Developing Assessment Models," ERDC/EL TR-01-30, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Wakeley, J. S. and R. D. Smith. 2001. "Hydrogeomorphic Approach to Assessing Wetland Functions: Guidelines for Developing Regional Guidebooks - Chapter 7 Verifying, Field Testing, and Validating Assessment Models," ERDC/EL TR-01-31, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Regional Guidebooks:

Ainslie, W.B., R. D. Smith, B. A. Pruitt, T. H. Roberts, E. J. Sparks, L. West, G. L. Godshalk and M. V. Miller. 1999. "A Regional Guidebook for Assessing the Functions of Low Gradient, Riverine Wetlands in Western Kentucky," Technical Report WRP-DE-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. (pending). View online or download part1.exe & part2.exe.

Smith, R. D. and C. V. Klimas. 2002. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley," ERDC/EL TR-02-4, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Shafer, D. J., B. Herczeg, D. W. Moulton, A. Sipocz, K. Jaynes, L. P. Rozas, C. P. Onuf and W. Miller. 2002. "Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Northwest Gulf of Mexico Tidal Fringe Wetlands," ERDC/EL TR-02-5, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Wilder, T.C. and T. H. Roberts. 2002. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Low-Gradient Riverine Wetlands in Western Tennessee," ERDC/EL TR-02-6, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Hauer, F. R., B. J. Cook, M. C. Gilbert, E. J. Clairain, Jr. and R. D. Smith. 2002. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains," ERDC/EL TR-02-7, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Rheinhardt, R. D., M. C. Rheinhardt and M. M. Brinson. 2002. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Wet Pine Flats on Mineral Soils in the Atlantic and Gulf Coastal Plains," ERDC/EL TR-02-9, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Noble, C. V., R. Evans, M. McGuire, K. Trott, M. Davis and E. J. Clairain, Jr. 2002. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Flats Wetlands in the Everglades," ERDC/EL TR-02-19, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Hauer, F. R., B. J. Cook, M. C.Gilbert, E. J. Clairain, Jr. and R. D. Smith. 2002. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains," ERDC/EL TR-02-21, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Uranowski, C., Z. Lin, M. DelCharco, C. Huegel, J. Garcia, I. Bartsch, M. S. Flannery, S. J. Miller, J. Bacheler and W. Ainslie. 2003. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Low-Gradient, Blackwater Riverine Wetlands in Peninsular Florida," ERDC/EL TR-03-3, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Noble, C. V., R. Evans, M. McGuire, K. Trott, M. Davis and E. J. Clairain, Jr. 2004. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Depressional Wetlands in Peninsular Florida," ERDC/EL TR-04-3, U. S. Army Engineer Research and Development Center, Vicksburg.

Stutheit, R. G., M. C. Gilbert, P. M. Whited and K. L. Lawrence. 2004. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Rainwater Basin Depressional Wetlands in Nebraska," ERDC/EL TR-04-4, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Klimas, C. V., E. O. Murray, J. Pagan, H. Langston and T. Foti. 2004. "A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley," ERDC/EL TR-04-16, U. S. Army Engineer Research and Development Center, Vicksburg. *Download Appendix D - Spreadsheets or download Appendix E - Spatial Data (ZIP Formats)*

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