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GUIDELINE FOR WETLAND ESTABLISHMENT ON RECLAIMED OIL SANDS LEASES

Alberta
ENVIRONMENT

GUIDELINE FOR WETLAND ESTABLISHMENT

ON RECLAIMED OIL SANDS LEASES

Prepared by the

Oil Sands Wetlands Working Group

Neil Chymko (Editor)

March 2000

This document is dedicated to the memory of Carl Surrendi whose presence and participation helped set the committee on its path. Although Carl did not see the completion of the guideline, his influence is felt throughout it. Carl had a long and distinguished career in environmental biology and we were fortunate to have his guidance in our efforts on wetland reclamation in the oil sands region.

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EXECUTIVE SUMMARY

The Athabasca Oil Sands Region, located in the Fort McMurray area of northeastern Alberta, is the province's largest and most accessible source of bitumen. Suncor Energy Inc. and Syncrude Canada Ltd. have operated surface oil sands mines and extraction/upgrading facilities since 1965 and 1978, respectively. Both companies are developing closure plans for current mine areas and opening up new mines. In addition, other operators such as Shell Canada Ltd. and Mobil Oil Canada Properties are developing plans to open new mines. Significant future growth in the oil sands industry is projected for the Fort McMurray area.

Wetlands are an important component of the natural landscape in the Athabasca Oil Sands Region. Bogs, fens, and marshes occur throughout the area, with bog and fen peatlands being the characteristic wetland type in the region. Wetlands are recognized as integral components of natural landscapes that provide diverse habitats and productive environments. Wetlands enhance environmental quality by increasing landscape diversity, providing habitat for a variety of fish and wildlife species, protecting and improving the quality of surface water and groundwater, controlling soil erosion and providing flood control. In addition, wetlands provide important economic resources and heritage values, including values associated with traditional land use.

Oil sands mining results in large-scale, extensive disturbance of natural landscapes, including wetlands on these landscapes. Operators must reclaim disturbed land and in this process wetlands are required as an integral part of the reclaimed landscape. Reclamation activities will be guided and directed by existing policy, legislation and planning initiatives, including: the Report and Recommendations of the Oil Sands End Land Use Committee, the Fort McMurray-Athabasca Integrated Resource Plan, the Recommended Wetland Policy for Alberta, the *Environmental Protection and Enhancement Act* (EPEA), the *Water Act* and the Oil Sands Regional Sustainable Development Strategy.

EPEA requires oil sands operators to reclaim disturbed land to an equivalent land capability that will support the intended end land uses on the reclaimed area. Consideration of the design and requirements of wetlands must be an integral part of mine planning and design, as well as mine closure planning. However, the province of Alberta currently does not have a guideline to assist in the establishment and evaluation of these wetlands.

The Oil Sands Wetlands Working Group was formed to develop a preliminary guideline that will be subject to further review and refinement. The Working Group had representation from government, industry, consulting, university and traditional communities. The Working Group was multi-disciplinary

and included persons with expertise in mine reclamation planning, hydrology, water chemistry, soils, peatlands, microbiology, aquatic biology, and waterfowl and wildlife ecology.

The guideline recognizes that development of oil sands leases through surface mining leads to significant alteration of landscape structure. Therefore, wetland reclamation goals will need to be compatible with conditions in this new landscape. Oil sands mining removes ecosystems on the mined site and alters ecosystems off-site, including the bog/fen ecosystem which dominates much of the wetland habitat in the oil sands region. The peatlands that will be removed cannot be replaced after mine closure since their development was the result of thousands of years of evolution. In addition, the characteristics of the post-mining landscape will not be conducive to the establishment of peatlands (e.g., changes in salinity). Currently, there are no techniques available to recreate bogs and fens on the reclaimed landscape.

The creation of shallow marshes in the reclaimed landscape is feasible and can be done in a manner that should provide many functions and values comparable to wetlands in the region. The ultimate objective is to provide sustainable, biologically diverse and productive wetlands in the reclaimed landscape. Although created wetlands will be different from pre-development wetlands, they should ensure a continuation of traditional uses as much as possible (e.g., trapping, hunting, and gathering of plants for food, medicinal, cultural and spiritual purposes).

The Wetlands Working Group identified a number of guiding principles that are essential to wetland development. In terms of a commitment to plan and create sustainable wetlands on reclaimed landscapes, the most notable requirements are:

Planning: Successful wetland reclamation must reflect a sound understanding of basic wetland structure and function, adequate timeframes to evaluate success, and the recognition of nature as a chief agent behind a wetland's "self-design" and ecological development. Sufficient attention must be paid to each step in the wetland reclamation process. Hydrology, hydrogeology, water quality, substrate and habitat design requirements will be the key "drivers" in wetland reclamation. Hydrology in particular is critical to sustainable wetland development. Planning will require proper studies to determine the required hydrology, drainage, topography, soils and vegetation characteristics of wetlands and their relationship to the surrounding landscape. As a result, wetland development requires a multi-disciplinary team comprised of engineering and environmental disciplines, as well as traditional ecological knowledge. In addition, wetland planning teams must be linked to closure planning teams and provide for input from aboriginal communities and other stakeholders.

Aboriginal Traditional Wetland Use. Existing wetlands in the oil sands region are highly valued by traditional land users (e.g., subsistence hunting, trapping and fishing, as well as food and plant gathering for medicinal, cultural retention and spiritual purposes). Wetland reclamation requires an understanding of these values and consultation with traditional land users to identify opportunities that arise during wetland reclamation to enhance wetland values for these users. Wetland reclamation must recognize the knowledge that aboriginal communities can bring to wetland planning and evaluation.

Adaptive Management: An adaptive management approach should be used to ensure design flexibility, overcome project concerns that may arise over time, and accommodate new ideas and principles for wetland development. Adaptive management recognizes that knowledge on the best practices for wetland establishment will evolve based on continued research and monitoring and the application of the knowledge gained. A flexible response capability will be required even after the establishment of wetlands, with mechanisms for input by the public and aboriginal peoples. The principle of adaptive management means that the techniques for wetland establishment may change over time. However, it does not mean that wetlands created using the best techniques available at the time should be significantly altered based on new knowledge gained after the wetlands were created. The new knowledge is best applied to new wetlands development.

Performance Assessment and Certification: Performance assessment goals, as well as reclamation guidelines and criteria, must be established to assess the physical, chemical and biological characteristics of wetlands established on reclaimed landscapes. These assessments are needed to determine whether a wetland is meeting its intended function (e.g., flood control, water treatment, habitat) and whether it is “free-to-evolve.” Criteria for assessing the performance and success of wetland reclamation must be site specific, measurable and based on a clear understanding of the functions to be provided. Selection of parameters for monitoring and assessment is currently confounded by the inherent inability of an immature wetland to exhibit functional equivalency to an older system (i.e., functions develop over long periods). In addition, reclaimed wetlands may have no clear analogue in the region (e.g., saline wetlands on CT deposits). Nevertheless, it will be possible to evaluate reclaimed wetlands. Social values such as traditional land uses will need to be considered in the evaluation.

The guideline presents an “approach” for the establishment of wetlands on reclaimed landscapes at oil sands mining operations. These wetlands will both reflect as well as affect the entire reclaimed terrestrial and aquatic landscape. Therefore, the approach considers overall landscape reclamation issues (e.g., topography, soils) as well as site-specific issues related to the intended function of a particular wetland (e.g., flood control, water treatment, habitat). The approach further recognizes that there is at least a 10 to 15 year timeframe for the establishment of a wetland on a reclaimed landscape. This timeframe is necessary to evaluate and confirm the establishment of a viable wetland that meets its intended functions and use.

The term “approach” is used because of:

1. the complexity of wetland establishment due to the different functions that wetlands provide on the reclaimed landscape (e.g., flood control, water quality improvement, habitat);

2. the interdisciplinary nature of wetland design and management and the technical complexity of the disciplines involved;

3. the knowledge that is expected to be gained to confirm the characteristics of reclaimed landforms, drainage patterns and established wetlands;

4. the potential changes that may occur in the nature of the final reclaimed landscape (e.g., due to changes in fine tails technology) which may have substantive impacts on the types of wetlands that can or should be created and the approach needed for their establishment;

5. the rapid rate of advancement in understanding wetland systems, natural and manmade, including information from pilot-scale tests and research in the oil sands area;

6. the need for long-term studies to confirm the development and performance of wetlands established on the reclaimed landscape;

7. the further clarification of end land use requirements that should come forward in the future;

8. the feedback that will take place among the various disciplines, the mine closure planning teams, regulators and aboriginal communities which will bring new information or perspectives forward that can be incorporated through adaptive management.

Rather than trying to be prescriptive and detailed, the guideline provides the framework for establishing wetlands, identifies and describes the issues that need to be addressed and provides general design considerations to deal with the issues. A series of appendices provide detailed information on a number of specific issues (e.g., natural wetlands in the region, landscape design factors, vegetation, fish and wildlife habitat, salinity, water quality of drained peatlands, water treatment wetlands, and traditional plants).

As outlined below, the approach provides a framework for the establishment of wetlands in the reclaimed landscape.

Wetland reclamation process

PLANNING AND DESIGN
Determination of the type and layout of wetlands to be created on the reclaimed landscape. Integration of wetland planning as part of mine design and closure planning. Evaluation of the major site and landscape factors required for wetland development and preparation of the design.

DEVELOPMENT AND MANAGEMENT
Development of the wetland according to the design and implementation of any necessary management of the wetland to achieve the intended function and use.

PERFORMANCE ASSESSMENT
Monitoring of physical, chemical and biological factors and evaluation of predicted performance or target values relative to observed performance and trends, as well as draft interim reclamation criteria.

RECLAMATION CERTIFICATION
Demonstration of successful reclamation in terms of physical, chemical and biological characteristics, adherence to the guideline and any approved plans, performance assessment, and interim reclamation criteria. Certification results in the return of the reclaimed land to the crown.

The guideline will provide both managers and technical staff with an approach to establish ecologically viable wetlands in reclaimed landscapes at oil sands mines. It will be used to prepare and review plans for the establishment of wetlands, to evaluate the performance of the wetlands, and to aid in the certification process once reclamation is considered complete. The guideline will also assist the public, in particular the aboriginal communities, to identify the value of wetlands and the role of the public in the establishment of wetlands.

The guideline contains seven sections. Section 1 provides an introduction to the document, including the intent and purpose, as well as the background to the establishment of the Oil Sands Wetland Working Group. Section 2 discusses the classification of natural wetlands, factors affecting wetland establishment, principles in wetland reclamation, government policy and legislation, as well as traditional use of wetlands. Section 3 outlines the objectives of the guideline for various users such as managers, technical staff, regulators and aboriginal communities.

Section 4 of the guideline provides the details of the wetland development approach at oil sands operations. The guideline identifies five types of wetlands:

1. **altered wetlands**
   - onsite or offsite wetlands that are not directly removed by mining but are potentially affected through drainage changes, water table drawdown, dewatering, etc
   - most are peatlands but some are marshes
   - may have substantial value, especially for traditional uses by aboriginal peoples
   - evaluation of their status and value, and the possible need to mitigate any adverse effects, is addressed through the environmental impact assessment (EIA) process with subsequent follow-up through the EPEA approvals for specific operations
   - if mitigation (i.e., conservation) is warranted, the intent is to monitor these wetlands to determine the nature of ecological changes, gain understanding of the effects, and undertake further action if warranted
   - given that altered wetlands are not "designed", the guideline does not focus heavily on them
2. **opportunistic wetlands**
   - wetlands that are not formally planned but arise inadvertently from depressions that form in the reclaimed landscape (i.e., due to differential settling of landforms), an increase in water tables or impeded drainage (surface or groundwater)
   - opportunistic wetlands can provide functions related to flood control, water quality improvement and habitat
   - a risk assessment would be carried out to determine their potential permanence and value on the landscape followed by a decision to remove, retain or enhance them
3. **constructed wetlands**
   - wetlands designed for a specific primary function (other functions will co-exist):
     - **water treatment:** to improve water quality through biological (e.g.,biodegradation), chemical (e.g., precipitation) or physical (e.g., dilution) processes; water quality could improve in terms of specific parameters, toxicity, etc; properly designed and functioning water treatment wetlands are viewed as effective, economical systems to treat process-affected waters released during the operational phase or the reclamation phase
     - **flood control:** to provide hydrological functions related to flood control and peak flow attenuation; to reduce or minimize downstream flooding; to promote flushing of saline waters; would consist of wide shallow areas to provide a large water retention capability
     - **habitat:** to provide wetlands for the purpose of their habitat value for plants, wildlife and traditional use; may have value as habitat for forage fish species
4. **vegetated watercourses**
   - wetlands designed as vegetated channels on the reclaimed landscape for the purposes of conveying water to wetlands, between wetlands, and offsite
   - vegetated watercourses are considered to be very important in the reclaimed landscape due to their value as riparian habitat (e.g., travel corridors, habitat connectivity, habitat diversity); although riparian areas may comprise a small percentage of the overall landscape their ecological value is disproportionately higher
   - vegetated watercourses can provide habitat for sport fish species downstream of end pit lakes

5. **littoral zones**
   - wetlands designed along the shore areas of reclaimed end pit lakes
   - littoral zones comprise shallow areas (< 2m deep) with emergent and submergent macrophytes
   - they are biologically productive and provide valuable wildlife and fisheries habitat
   - littoral zones can also provide hydrological (e.g., shoreline protection) and water quality improvement functions

The guideline provides an overall Wetland Management Flow Chart as an overview and guide to the establishment of the five types of wetlands. To facilitate wetland design the guideline presents the following information in sequence for each type of wetland:

1. general description to provide an overview, rationale and comments;
2. development flow chart to outline the design and implementation process;
3. key issues checklist to identify key design factors and selected design recommendations;
4. development approach sheet to provide a form that can be used to design the wetland.

Section 5 of the guideline provides a framework for the performance assessment of reclaimed wetlands. Performance assessment, as used in this guideline, means the monitoring of physical, chemical, and biological factors and evaluation of predicted performance or target values with observed performance and trends, as well as draft interim reclamation criteria (Section 6). Specific performance assessment criteria cannot be provided at the present time since specific reclamation criteria are not yet finalized. Performance will be considered "successful" when the values for a particular characteristic fall within an acceptable range of target values for that characteristic (e.g., design values or values from benchmark/reference wetlands). Performance assessments can be done both during the operation phase (e.g., water quality improvement in a water treatment wetland) and the reclamation phase.

The guideline provides an initial framework for performance assessment based on key issues (i.e., hydrological, physical, biological, chemical), performance indicators, measurement endpoints, performance assessment targets, potential cause of failures, prevention of failures through initial design, and mitigation of failures (if they occur) through adaptive management. The guideline also provides suggested monitoring parameters for wetlands.

Section 6 of the guideline outlines the reclamation certification process, information requirements for applications for a reclamation certificate, as well as interim general reclamation criteria for landscape, soil and vegetation characteristics. Government, industry and the public will continue to work toward the development of reclamation criteria for wetlands.

Section 7 presents a number of recommendations to advance the knowledge base on wetland reclamation. The recommendations identify a large number of potential research projects associated with general and specific issues.

General Issues	Specific Research Issues
1. Pilot-scale demonstration of treatment wetlands	1. Bioaccumulation
2. Pilot-scale demonstration of habitat wetlands	2. CT characteristics
3. Wetlands Working Group	3. CT landforms
4. Water discharge policy	4. Salinity impacts on vegetation
5. Reclamation certification	5. Salinity impacts on waterfowl
6. Wetland management	6. Naphthenic acids
7. Technology transfer	7. Air emissions
	8. Biogenic gases
	9. Wetland reclamation modeling
	10. Vegetation
	11. Wetlands sustainability
	12. Littoral zones
	13. Wetland soils
	14. Peatlands
	15. Riparian reclamation
	16. Traditional use of wetlands

The Oil Sands Wetlands Working Group conducted a ranking process to determine the relative priority of various research areas. Appendix J provides the details of the process used. The ranking considered the degree of concern and the degree of knowledge on various issues. Areas with the highest priority were those characterized by high concern and low level of knowledge (i.e., a high need for greater knowledge).

Issues associated with the establishment of wetlands on consolidated or composite tails (CT deposits) were identified as the highest priority for research.

1. Water Chemistry

    - salinity in wetlands on CT deposits
    - water release rates of CT deposits
    - treatment capability of wetlands on CT deposits

2. Biology

    - diversity in wetlands on CT deposits
    - bioaccumulation in wetlands on CT deposits
    - chronic toxicity in wetlands on CT deposits
    - chronic toxicity in wetlands on tailings sands
    - riparian areas on CT deposits
    - connector streams on CT deposits

3. Physical
    - hydrology on CT deposits

4. Traditional Land Use
    - traditional uses of wetlands on CT deposits

To assist in the establishment of wetlands on reclaimed landscapes, the guideline includes a number of appendices that provide more detailed information on particular topics. The topics addressed include:

1. Natural wetlands in the oil sands region	Appendix B
2. Landscape design considerations	Appendix C
3. Hydrology and vegetation considerations	Appendix D
4. Fish and wildlife considerations (including waterfowl)	Appendix E
5. Salinity	Appendix F
6. Water quality from drained peatlands	Appendix G
7. Constructed wetlands for water treatment	Appendix H
8. Traditional plants	Appendix I
9. Reclamation research priorities	Appendix J
10. CONRAD research projects	Appendix K

In summary, the *Guideline for the Establishment of Wetlands on Reclaimed Oil Sands Leases* presents an approach for the establishment of wetlands on reclaimed oil sands landscapes. The concepts and numerical values presented in the document represent the best available information at the time the report was completed. By necessity the guideline will be subject to further review and refinement as new knowledge is gained through research, pilot-scale tests, monitoring and experience with using the guideline. Through adaptive management this new knowledge will be used to improve the process and methods for establishing wetlands at oil sands operations.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Organizations/Legislation/Policy

AENV	Alberta Environment
AEP	Alberta Environmental Protection (renamed as Alberta Environment in May 1999)
AWRC	Alberta Water Resources Commission
CEATAG	CONRAD Environmental Aquatic Technical Advisory Group
CONRAD	Canadian Oil Sands Network for Research and Development
EIA	Environmental Impact Assessment
EPEA	Environmental Protection and Enhancement Act
EUB	Alberta Energy and Utilities Board
IRP	Integrated Resource Plan
NWWG	National Wetlands Working Group
OSWRTWG	Oil Sands Water Release Technical Working Group
RAC	Oil Sands Reclamation Advisory Committee
RMA	Resource Management Area
SETAC	Society of Environmental Toxicology and Chemistry

Technical Terms

AWHC	available water holding capacity
BOD	Biological Oxygen Demand
CT	consolidated/composite tailings
C	carbon
DO	dissolved oxygen
HRT	hydraulic retention time
N	nitrogen
P	phosphorus
PAH	polyaromatic hydrocarbon
TDS	total dissolved solids
TSS	total suspended solids

1. INTRODUCTION TO THE GUIDELINE

1.1 General

The Athabasca Oil Sands Region, located in the Fort McMurray area of northeastern Alberta, is the province's largest and most accessible source of bitumen. Suncor Energy Inc. (Suncor) and Syncrude Canada Ltd. (Syncrude) have operated surface oil sands mines and extraction/upgrading facilities since 1965 and 1978, respectively. Both companies are developing closure plans for current mine areas and opening up new mines. In addition, other operators such as Shell Canada Ltd. (Shell) and Mobil Oil Canada Properties (Mobil) are developing plans to open new mines. Significant future growth in the oil sands industry is projected for the Fort McMurray area.

Wetlands are an important component of the natural landscape in the Athabasca Oil Sands Region. Bogs, fens, and marshes occur throughout the area, with bog and fen peatlands being the characteristic wetland type in the region. Wetlands are recognized as integral components of natural landscapes that provide diverse habitats and productive environments (Westworth 1993). Wetlands enhance environmental quality by increasing landscape diversity, providing habitat for a variety of fish and wildlife species, protecting and improving the quality of surface water and groundwater, controlling soil erosion and providing flood control. Wetlands are recognized as valuable natural resources with broad biotic and abiotic functions. In addition, wetlands provide important economic resources and heritage values, including values associated with traditional land use.

Oil sands mining results in large-scale, extensive disturbance of natural landscapes, including wetlands on these landscapes. Operators must reclaim disturbed land and wetlands are required as an integral part of the reclaimed landscape. Reclamation will be guided and directed by existing policy, legislation and planning initiatives, including: the Report and Recommendations of the Oil Sands Mining End Land Use Committee, the Fort McMurray-Athabasca Integrated Resource Plan, the Recommended Wetland Policy for Alberta, the *Environmental Protection and Enhancement Act* (EPEA), the *Water Act*, and the Oil Sands Regional Sustainable Development Strategy.

EPEA requires oil sands operators to reclaim disturbed land to an equivalent land capability that will support the intended end land uses on the reclaimed area. Consideration of the design and requirements of wetlands must be an integral part of mine planning and design, as well as mine closure planning. However, the province of Alberta currently does not have a guideline to assist in the establishment and evaluation of these wetlands. This document provides a preliminary guideline that will be subject to further review and development.

1.2 Establishment of the Oil Sands Wetlands Working Group

Government and industry agreed on the need to form an Oil Sands Wetlands Working Group to look at wetland reclamation at oil sands mines. The need arose primarily from the following:

1. Current regulatory approvals and the Report and Recommendations of the Oil Sands Mining End Land Use Committee (1997) recognized that wetlands will be an integral component of landscapes at oil sands mines.
2. Government agencies are anticipating applications that include wetlands in reclaimed landscapes. In addition, these applications may have to address the mitigation of impacts on wetland areas adjacent to oil sands mining operations.
3. Wetlands are complex systems in terms of hydrology, hydrogeology, chemistry and biology. The requirements for wetland establishment are not fully understood at present. Further, wetlands and terrestrial landforms are interrelated and must be planned and developed recognizing this interrelationship.
4. Guidelines for wetland establishment in the oil sands region would be beneficial for industry, government and the public, including aboriginal communities.

The Wetlands Working Group had representation from industry, government, consultants, university and aboriginal communities (Appendix A). The group was co-chaired by industry and government.

1.3 Intent and Purpose of the Guideline

This document has been developed as a guide for the planning and design, development and management, performance assessment and certification of reclaimed wetlands (Figure 1.1).

Figure 1.1 Wetland reclamation process

PLANNING AND DESIGN Determination of the type and layout of wetlands to be created on the reclaimed landscape. Integration of wetland planning as part of mine design and closure planning. Evaluation of the major site and landscape factors required for wetland development and preparation of the design. DEVELOPMENT AND MANAGEMENT Development of the wetland according to the design and implementation of any necessary management of the wetland to achieve the intended function and use. PERFORMANCE ASSESSMENT Monitoring of physical, chemical and biological factors and evaluation of predicted performance or target values relative to observed performance and trends, as well as draft interim reclamation criteria. RECLAMATION CERTIFICATION Demonstration of successful reclamation in terms of physical, chemical and biological characteristics, adherence to the guideline and any approved plans, performance assessment, and interim reclamation criteria. Certification results in the return of the reclaimed land to the crown.

The objective of this guideline is to provide an **approach** for the establishment of ecologically viable wetlands in landscapes impacted by oil sands mining. Managers and technical staff require this information to design and develop wetlands and, subsequently, to evaluate them through performance assessment and certification. The guideline will be used to prepare and review applications for wetlands, to evaluate performance, and to aid in the certification process once reclamation of the wetland is considered complete. The guideline will also assist the public, in particular aboriginal communities, to understand the function and value of wetlands and to participate in the establishment of wetlands on reclaimed landscapes.

The term “approach” is used because of:

1. the complexity of wetland establishment due to the different functions that wetlands provide on the reclaimed landscape (e.g., flood control, water quality improvement, habitat);

2. the interdisciplinary nature of wetland design and management and the technical complexity of the disciplines involved;

3. the knowledge that is expected to be gained to confirm the characteristics of reclaimed landforms, drainage patterns and established wetlands;

4. the potential changes that may occur in the nature of the final reclaimed landscape (e.g., due to changes in fine tails technology) which may have substantive impacts on the types of wetlands that can or should be created and the approach needed for their establishment;

5. the rapid rate of advancement in understanding wetland systems (natural and manmade), including information from pilot-scale tests and research in the oil sands area;

6. the need for long-term studies to document and evaluate the development and performance of wetlands established on the reclaimed landscape;

7. the further clarification of end land use requirements that should come forward in the future;

8. the feedback that will take place among the various disciplines, the mine closure planning teams, regulators and aboriginal communities which will bring new information or perspectives forward that can be incorporated through adaptive management.

The guideline provides an engineering and biological approach, supported by technical information, for the development of the wetland types that are likely to characterize the post-development landscape at oil sands mines. The guideline does not provide, at the present time, detailed criteria for certification of reclaimed wetlands. It does, however, discuss the framework for certification and provide draft interim reclamation criteria as a starting point for the further development of criteria.

The term “wetlands” as used in the guideline means “marshes” and “peatlands” (as defined below) and the connecting watercourses between these wetlands. The document does not address guidelines for creating lakes in the reclaimed landscape; however, the shallow, littoral zones around lakes are considered in the guideline as one of the wetland types in the reclaimed landscape.

2. BACKGROUND

2.1 Classification of Natural Wetlands

Wetlands are areas that are flooded or saturated by surface or groundwater for long enough periods to support vegetation that is adapted to saturated soil conditions (Westworth 1993). The Alberta Water Resources Commission (AWRC) provides an overview of wetland classification in the *Recommended Wetland Policy for Alberta* (AWRC 1994). Wetlands in Canada are categorized into five major classes. Three are non-peat forming while two are peat forming. Non-peat forming wetlands include shallow open water (less than two metres deep), marshes and swamps. Peat forming wetlands include bogs and fens. For the purposes of wetland policy and management in Alberta, wetlands are grouped into two major classes: slough/marsh wetlands and peatlands. Swamps and shallow open water are recognized as a component of the adjacent slough/marsh or peatland (AWRC 1994).

A “slough/marsh wetland” means an area that is permanently or periodically inundated by standing or slow-moving water and is characterized by emergent vegetation. Water levels may fluctuate and open water may or may not be present. Slough/marsh is a broad term and includes sloughs, marshes and adjacent areas of shallow open water. For the purpose of this guideline, a slough/marsh wetland is referred to as a “marsh.”

A “peatland” includes bogs, fens, and any contained areas of shallow open water. Peatlands, commonly referred to as muskeg, are permanent wetlands characterized by the accumulation of peat derived from plant material such as mosses and sedges. The water table is often at or near the ground surface. Bogs get most of their water from precipitation while fens are supplied primarily through groundwater (AWRC 1994).

Most of Alberta’s wetlands are situated in the northern third of the province within the Boreal Forest Natural Region. Bog and fen peatlands are the characteristic wetland type in this region (Westworth 1993, Vitt et al. 1996). Appendix B provides more detailed information on wetland classification and ecology, as well as a comparison of the five wetland classes used in the *Alberta Wetlands Inventory* (Halsey and Vitt 1996) to ecosites in the *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald 1996).

2.2 Factors Affecting the Establishment of Wetlands in the Oil Sands Region and Their Implications in Reclaimed Landscapes

Climate. Climate is a key factor in the distribution of wetlands in Alberta. The cool, moist climate of northern Alberta supports the development of peat accumulating wetlands. Although reclaimed wetlands may evolve towards peatlands, this will occur over a very long timeframe given the slow rate of accumulation of organic material. From a reclamation planning perspective, climate is not a factor that can be controlled.

Salts. The presence or absence of salts within the substrate is a significant factor explaining wetland variation across Alberta. Areas with similar climates have much higher amounts of non-peat accumulating wetlands when associated with solonetzic soils (Vitt et al. 1996). This can be related to the inability of mosses to establish viable communities in areas where saline conditions occur (Vitt et al. 1993). Given the saline nature of some materials within the reclaimed landscape (e.g., consolidated tailings, sodic overburden), salinity will be a key factor to consider in wetland establishment.

Substrate texture, topography and bedrock geology. These three factors have also been identified as important controls on wetland type and distribution (Halsey et al. 1997). Substrates with high hydraulic conductivity support patterned fens in climatically conducive areas, while non-patterned fens and bogs are found associated with substrates of relatively low hydraulic conductivity. Wetlands are extensive in areas with minimal topographic relief and poorly integrated drainage, particularly along major drainage divides such as Alberta’s northern uplands. With respect to geology, acidic bedrock supports higher bog cover than calcareous bedrock where fends dominate.

Implications to wetland reclamation at oil sands mines. Development of oil sands leases will lead to significant alteration of landscape structure. Wetland reclamation goals will need to be compatible with conditions in this new landscape. Wetland types in the post-development and reclaimed landscape will be significantly different than pre-development wetlands since geologic factors controlling wetland distribution will have changed in terms of topography, drainage patterns, substrate characteristics, and groundwater chemistry. Based on observations of the factors that influence wetland formation and distribution, and the predicted future characteristics of the reclaimed landscape, it is not feasible to reclaim to peatlands in the short-term.

Oil sands mining removes ecosystems on the mined site and alters ecosystems off-site, including the bog/fen ecosystem which dominates much of the wetland habitat in the oil sands region. Peatlands that will be removed cannot be replaced after mine closure since their development was the result of many thousands of years of evolution (Environment Canada 1985) and post-mining conditions will not be conducive to the formation of the vegetation communities typically associated with peatlands. The creation of shallow marshes in the reclaimed landscape is feasible and can be done in a manner that should provide many functions and values comparable to wetlands in the region.

Wetlands will be an integral part of the reclaimed landscape and will need to be incorporated into mine closure planning to conform to land capability objectives and end land use goals. In addition, wetlands adjacent to the mine site may require some level of maintenance to maintain their viability if conservation of the wetland is identified as an objective. Goals for wetland reclamation might include:

- retain similar land uses (e.g., flood control, wildlife habitat, trapping, traditional land use);
- incorporate new land uses desired by the local community, including aboriginal communities (e.g., recreation, traditional land use);
- moderate any impacts of landscape disturbance during and after mining (e.g., water quality improvement of water that is slowly released from tailings sand storage deposits or overburden disposal sites).

Reclaimed wetlands will both reflect and affect the reclaimed landscape. Therefore, the development approach for wetlands will have a substantive impact on mine closure planning for both aquatic and terrestrial areas on the entire mine site and will need to be thoroughly integrated in the end land use planning process:

1. Wetlands reflect the landscape due to issues such as sediment yield (i.e., the rate of soil erosion and subsequent infilling of wetlands), which is a function of slope stability, soil and vegetation types and drainage regimes. Therefore, the requirement for a certain wetland type and longevity on a reclaimed landscape will have a substantive influence on the design of the surrounding uplands (e.g., topography, soil type, vegetation community).

2. Wetlands affect the landscape by virtue of their capabilities to retain water and decrease its velocity (i.e., erosion control), to provide vegetation and wildlife habitat, and to enhance water quality which is a principal determinant controlling the characteristic of any wetland habitat.

2.3 Guiding Principles in Oil Sands Wetland Reclamation

The Wetlands Working Group developed a number of principles to guide the establishment of wetlands in the oil sands region.

Wetland Function: Wetlands provide many functions and values integral to a properly reclaimed landscape. Functions include ecological (habitat for a wide diversity of plant and animals), hydrological (flood buffering, water storage, groundwater discharge and recharge, surface flow augmentation), and water quality (improvement of chemical, physical and biological characteristics).

Wetland Values: Values are associated with the production or provision of a commodity or product. Wetlands can provide economic values (e.g., production of plants and animals for subsistence aboriginal use and trapping, production of other economically important flora and fauna, value to tourism, farming, agriculture) and heritage values (e.g., recreation, education, science, spiritual and cultural continuation for aboriginal communities).

Aboriginal Traditional Wetland Use: Existing wetlands in the oil sands region are highly valued by First Nation and Métis traditional land users. Traditional land use comprises a complex of uses including subsistence hunting, trapping and fishing, as well as food and plant gathering for medicinal purposes. Spiritual and cultural values associated with particular species, areas or activities are also important. Wetland reclamation requires an understanding of these values and consultation with traditional land users to identify opportunities that arise during wetland reclamation to enhance wetland values for these users. Wetland reclamation must recognize the knowledge that aboriginal communities can bring to wetland planning and evaluation.

Conservation of wetlands: The conservation of natural wetlands is an important means of maintaining wetland functions and values. This can include opportunities to avoid direct loss of wetlands through mine planning, as well as opportunities to minimize or mitigate indirect effects (e.g., water table drawdown) on wetlands adjacent to oil sands operations.

Sustainability: Successful wetland development requires the establishment of a biologically viable and sustainable wetland system. Once established, the system should be free to evolve as a functioning system without requiring future maintenance or management. The establishment period is expected to be in the order of 10 to 15 years. At that point, the system should be set on a path of ecological succession and development. Wetland systems, including watercourses, should not require long-term maintenance and management. In addition, they will have to attain a certain level of maturity before it can be determined that they are sustainable.

Planning: Successful wetland reclamation must reflect a sound understanding of basic wetland structure and function, adequate timeframes to evaluate success, and the recognition of nature as a chief agent behind a wetland's "self-design" and ecological development. Sufficient attention must be paid to each step in the wetland reclamation process. Hydrology, hydrogeology, water quality, substrate and habitat design requirements will be the key "drivers" in wetland reclamation. Hydrology in particular is critical to sustainable wetland development. Planning will require proper studies to determine the required hydrology, drainage, topography, soils and vegetation characteristics of wetlands and their relationship to the surrounding landscape. As a result wetland development requires a multi-disciplinary team comprised of engineering and environmental disciplines, as well as traditional ecological knowledge. In addition, wetland planning teams must be linked to closure planning teams and provide for input from aboriginal communities and other stakeholders.

Practical methods: Wetland reclamation will require practical, feasible and reasonable methods and procedures that will evolve as improved and new technologies are established.

Adaptive management. An adaptive management approach should be used to ensure design flexibility, overcome project concerns that may arise over time, and accommodate new ideas and principles for wetland development. Adaptive management recognizes that knowledge on the best practices for wetland establishment will evolve based on continued research and monitoring and the application of the knowledge gained. A flexible response capability will be required even after the establishment of wetlands, with mechanisms for input by the public and aboriginal peoples. The principle of adaptive management means that the techniques for wetland establishment may change over time. However, it does not mean that wetlands created using the best techniques available at the time should be significantly altered based on new knowledge gained after the wetlands were created. The new knowledge is best applied to new wetlands development.

Performance assessment and certification: Performance assessment goals, as well as reclamation guidelines and criteria, must be established to assess the physical, chemical and biological characteristics of wetlands established on reclaimed landscapes. These assessments are needed to determine whether a wetland is meeting its intended function (e.g., flood control, water treatment, habitat) and whether it is "free-to-evolve." Criteria for assessing the performance and success of wetland reclamation must be site specific, measurable and based on a clear understanding of the functions to be provided. Selection of parameters for monitoring and assessment is currently confounded by the inherent inability of an immature wetland to exhibit functional equivalency to an older system (i.e., functions develop over long periods). In addition, reclaimed wetlands may have no clear analogue in the region (e.g., saline wetlands on CT deposits). Nevertheless, it will be possible to evaluate reclaimed wetlands. Social values such as traditional land uses will need to be considered in the evaluation.

Constructed wetlands: There should be recognition that constructed wetlands will have a well-developed, sustainable biological community; however, it may not be representative of natural undisturbed wetlands in the region. Constructed wetlands may exhibit effects from reclamation release waters but will be biologically active and inhabited by a sustainable community of organisms. This community should be ecologically viable and able to provide vegetation and habitat for traditional use, but may not be fully representative of undisturbed habitats.

Biological diversity and use of native species: Wetland reclamation should promote biological diversity at the landscape, community and species levels. In addition, the use of native species is strongly encouraged.

2.4 Government Policy, Regulatory Framework and Planning Initiatives

As previously noted, wetlands will be an integral component of the reclaimed landscape. There are a number of government policies, regulatory requirements and planning initiatives that relate to wetland reclamation. These are briefly discussed below.

2.4.1 Oil Sands Mining End Land Use Committee

Overview. The Oil Sands End Land Use Committee was established to make recommendations related to end land use at oil sands mines. The recommendations were intended to:

1. provide direction regarding the end land use of reclaimed lands at oil sands mines;

2. promote an integrated, regional approach to end land use with the goal of reducing the regulatory review cycle time and regulatory uncertainty for the oil sands industry, other industry sectors, all levels of government and the public;

3. provide recommendations that can be considered during the detailed reclamation planning and regulatory review process;

4. provide direction on the general timing of the initiation of end land uses;

5. consider the consistency of committee recommendations with provincial and municipal legislation, plans, policies and programs, as well as short and long-term provincial, municipal, local and corporate priorities and fiscal realities.

Relation to wetland reclamation. The *Report and Recommendations of the Oil Sands Mining End Land Use Committee* (Oil Sands Mining End Land use Committee 1997) identified three main land use categories: (1) Natural and Conservation Areas, (2) Human Development, and (3) Forestry. The Natural and Conservation Areas includes areas that support forest, wetlands, waterbodies, bogs, fens, regional drainage patterns, lakes, shrub lands, transitional vegetation and riparian areas.

The End Land Use Committee stated that Natural Areas (which include wetlands) are an integral part of oil sands mining reclamation and are important to ensure that biodiversity is maintained. The committee recommended that reclamation of natural and conservation areas consider biodiversity, aesthetics, traditional land uses and general community uses such as hunting, fishing, trapping and gathering of plants. The committee also indicated that reclamation should ensure the evolution of productive natural ecosystems with the objective of re-establishing a diversity and abundance of wildlife habitat types and qualities consistent with pre-disturbance levels.

Relation to the guideline. The guideline for wetland reclamation provides direction that will build on the recommendations of the End Land Use Committee. The guideline also serves as input to the committee in further deliberations by the Athabasca Oil Sands Reclamation Advisory Committee on end land use planning in the oil sands region (see next section).

2.4.2 Athabasca Oil Sands Reclamation Advisory Committee (RAC)

Overview. The Reclamation Advisory Committee was established in early 1999 to follow-up on the direction and recommendations of the Oil Sands Mining End Land Use Committee. The committee has representation from the provincial government, federal government, Municipal District of Wood Buffalo, oil sands operators, aboriginal communities, and the forestry industry. The purpose of the committee is to make integrated and regionally sound recommendations regarding reclamation and appropriate end land uses. The committee serves a steering group for working groups addressing various operational issues associated with oil sands mining, including the development of guidelines where needed.

Relation to wetland reclamation. The Reclamation Advisory Committee provides a forum to make recommendations respecting reclamation and end land use, including matters related to wetland reclamation.

Relation to the guideline. The Reclamation Advisory Committee recommended that the guideline be released and used by government, industry and stakeholders for a period of time. Subsequently the guideline will be reviewed to see what changes may be needed.

2.4.3 Fort McMurray-Athabasca Subregional Integrated Resource Plan (IRP)

Overview. The Integrated Resource Plan (AEP 1996) provides guidance on land use to resolve issues and conflicts on public land and resources through the integration of objectives and by providing guidelines to achieve these objectives. The IRP establishes Resource Management Areas (RMA's) to guide resource and land use management. Each RMA is identified on the basis of a common landscape, its current land use and its resource capability.

Oil sands mining will primarily occur in two RMA's: the Athabasca-Clearwater RMA and the Mildred-Kearl Lakes RMA. The former RMA encompasses the valleys of the Athabasca, Clearwater, Ells, Muskeg and Firebag Rivers. The latter occupies a major portion of the IRP planning area and is underlain by surface mineable oil sands deposits.

Relation to wetland reclamation. The broad objectives and guidelines in the IRP should be considered during wetland reclamation planning to ensure consistency with the IRP and to see what opportunities exist to meet some of the objectives with respect to resources such as wildlife. Operators will need to identify the RMA that applies to their development area and then refer to the broad resource/land use objectives and guidelines that apply to the planning area.

Relation to the guideline. The guideline for wetland reclamation provides direction to oil sands operators and government to create wetlands in reclaimed landscapes that will be consistent with the intent of the IRP. The guideline does not address decisions related to end land use planning, including uses to be provided by wetlands at a specific oil sands site. Land use issues for a proposed oil sands operations are initially considered during the Environmental Impact Assessment (EIA) process and the decision-making process of the Alberta Energy and Utilities Board (EUB). These processes would consider the direction, objectives and guidelines in the IRP. Ultimately, land use decisions will be made by Alberta Environment through regulatory approvals, land management mechanisms, and the coordinating role provided by the Reclamation Advisory Committee. The committee will consider the activities being conducted by all operators in the IRP area and the recommendations of the Oil Sands Mining End Land Use Committee and will make recommendations regarding end land uses.

2.4.4 Recommended Wetland Policy for Alberta

Overview. This policy (Alberta Water Resources Commission 1994) provides direction for the conservation and management of wetlands in Alberta. The policy states that *"Wetlands are an integral and important part of our environment and provide many environmental, economic and social benefits."* The overall goal of the policy is to sustain these benefits. To achieve this goal the government has three major tools: it can preserve wetlands from use, it can allow careful development of wetland resources, and it can restore or create wetlands in areas where they have been lost. The policy recognizes that the interrelationship between wetlands and landscape is critical to wetland functions and values and that the variety of wetland functions and values needs to be reflected in decision-making. The policy further recognizes that wetlands are dynamic systems and need to be managed as ecosystems. The policy provides a broad framework for wetland management within which regional goals and guidelines will have to be set.

Relation to wetland reclamation. The policy relates to wetlands in the oil sands region in terms of decisions to preserve wetlands (i.e., their value is such that they should be protected from direct or indirect impacts from oil sands development) and plans to restore, enhance or create wetlands (i.e., establishment of wetlands in the reclaimed landscape). Normally, the decision to preserve or protect certain wetlands would occur during the EIA process and the decision-making process of the Alberta Energy and Utilities Board (EUB). These processes would consider the direction, objectives and guidelines in the Athabasca-Fort McMurray Integrated Resource Plan. The EUB would also deal with the broad, conceptual framework of the project, including the conceptual conservation and reclamation plan.

Plans regarding the creation of specific wetlands in the reclaimed landscape would be dealt with through the regulatory approvals required under the *Environmental Protection and Enhancement Act* (EPEA) and the *Water Act.*

Relation to the guideline. The guideline for wetland reclamation provides direction to oil sands operators and government on the creation of wetlands in reclaimed landscapes. The wetland policy recognizes wetland creation as one of the tools to sustain the benefits provided by wetlands. The guideline assists operators in meeting the regulatory requirements under EPEA and the *Water Act.* The guideline does not address decisions related to EIA and EUB processes (e.g., what wetlands should be protected in the pre-development landscape).

2.4.5 Environmental Protection and Enhancement Act (EPEA)

Overview. The *Environmental Protection and Enhancement Act* (EPEA) and its regulations provide a comprehensive set of legislation intended to protect the environment and achieve sustainable development.

Under its environmental assessment provisions, EPEA requires the proponent of an oil sands mine to prepare an Environmental Impact Assessment (EIA) report. The EIA is filed as part of the application for an oil sands approval from the Alberta Energy and Utilities Board (EUB). The EIA is used by the EUB in its evaluation of the social, economic and environmental effects of the proposal and its determination of whether the project is in the public interest. The EUB process sets the broad, conceptual framework for the project, including the conceptual reclamation plan. In this context, the EIA/EUB process considers matters related to the preservation or protection of wetlands in the pre-disturbance landscape, the mitigation measures required to achieve this, and the general nature of landscape types, including wetlands, that will occur in the reclaimed landscape.

EPEA requires an operator to conserve and reclaim land disturbed or affected by an industrial activity such as an oil sands mine and to obtain a reclamation certificate. EPEA also requires the operator of an oil sands mine to apply for and obtain an approval for the opening up, operation and reclamation of a mine. The EPEA application must include detailed operational plans for conservation and reclamation of the land affected by oil sands development, including the detailed plans for the establishment of wetlands on the reclaimed landscape. A fundamental component of EPEA is the expectation for public consultation in the preparation of applications and the provision for public involvement in the review of these applications.

Under EPEA, the *Conservation and Reclamation Regulation* establishes the objective of reclamation as the return of equivalent land capability. The return of equivalent land capability means that the ability of land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that individual land uses will not necessarily be identical. Land capability is the ability of land to support a given land use (e.g., agriculture, forestry, wildlife habitat, recreation, etc.) based on an evaluation of the physical, chemical and biological characteristics of the land, including landscape (topography, drainage, hydrology), soils and vegetation.

This objective of equivalent land capability provides for sustained levels of use at least equivalent to those that existed prior to development. The concept provides for flexibility such that individual land capabilities and land uses may change, but overall land capability and land use will be equivalent to pre-disturbance conditions. Although reclaimed landscapes may differ from pre-disturbance conditions, they should normally be characteristic of the region. If they are not completely characteristic, they must be sustainable landscapes with viable biological communities that are acceptable to the government and stakeholders.

Relation to wetland reclamation. EPEA and its regulations provide the regulatory framework for reclamation. Reclamation of disturbed land to wetlands will require an application for approval containing the information needed to evaluate the proposed wetland. Under EPEA, the expectation is that the public will be appropriately consulted in the preparation of wetland reclamation plans.

When reclamation of the wetland is considered complete, the operator will have to apply for and obtain a reclamation certificate. General information requirements are listed in the *Conservation and Reclamation Regulation.* An oil sands operator must obtain a reclamation certificate to demonstrate that reclamation has been successful. If specific criteria or land capability evaluation procedures are available they are used to assess reclamation. In the absence of these, an evaluation of the reclaimed wetland would be completed. Certification would consider compliance with the EPEA approval (i.e., the plans in the application for approval as modified by any approval conditions that may apply), information presented in this guideline, performance assessment evaluations, as well as any reclamation guidelines or criteria that are in effect. The guideline presents draft interim reclamation criteria for landscape, soil and vegetation parameters related to wetland reclamation (see Section 6). On submission of the application for a certificate, regulatory staff from the required disciplines would review the application, conduct site inspections and provide recommendations for a final decision on the application. An inspector would then hold an inquiry to determine if the certificate should be issued.

Relation to the guideline. The guideline outlines to operators and the public the legislative requirements and expectations of the government with respect to wetland reclamation. The guideline will assist operators in preparing wetland reclamation plans that will be included in applications for EPEA approvals. The guideline will assist government staff in reviewing applications for approval, as well as applications for reclamation certificates. As noted above, the guideline presents draft interim reclamation criteria for wetlands. The process of adaptive management will allow wetland reclamation planning and assessment to remain up-to-date (e.g., through meetings, field tours, workshops).

2.4.6 Water Act

Overview. The *Water Act*, which was proclaimed in 1998 and came into effect on January 1, 1999 promotes and supports the conservation, management and wise use of water in Alberta. An important component of the Act is the protection and enhancement of aquatic habitat and the development of a planning framework to help guide future decision-making.

All water in Alberta is vested in the Crown. As such, activities involving the creation of wetlands or alteration of drainage patterns are subject to review and approval under the *Water Act* and its regulations. Approvals may be subject to guidelines established under regional water management plans developed pursuant to the Act. Approvals will also be subject to public review.

Relation to wetland reclamation. The establishment of wetlands and associated habitat on reclaimed oil sands mine sites is consistent with the philosophy of the Act and the province's policies on wetland conservation and management. The applications and approvals required for the establishment of wetlands on reclaimed mine sites will be closely tied to approvals and reclamation certificates issued under the *Environmental Protection and Enhancement Act.* The term of approvals will match the timeframe required by industry to initially establish the wetland and will allow for future adaptive management until the wetland is considered reclaimed.

Relation to the guideline. The guideline outlines to operators and the public the legislative requirements under the *Water Act* and expectations of the government with respect to wetland reclamation. The guideline assists operators in preparing applications for approvals under the *Water Act* and government staff in reviewing and approving applications.

2.4.7 Regional Sustainable Development Strategy for the Athabasca Oil Sands Area (RSDS)

Overview. In response to the significant interest in the development of Alberta's oil sands, Alberta Environment recognized the need to develop a regional strategy for sustainable oil sands development coupled with strong environmental management and protection. The *Regional Sustainable Development*

Strategy for the Athabasca Oil Sands Area was released in August 1999. The strategy creates a structure that brings all stakeholders together to discuss and resolve issues surrounding sustainable development. An adaptive management framework will be used to address various environmental issues or "themes." The strategy will consider regional cumulative effects, environmental thresholds, appropriate monitoring techniques, resource management approaches, knowledge gaps, and research to fill gaps. The strategy will ensure that comprehensive information is available to guide decision-makers. The RSDS provides a blue print for further action which will be tracked and implemented over time. This action may include initiatives related to wetland conservation, reclamation and end use, as well as research needs.

2.5 Traditional Use of Wetlands

2.5.1 Introduction

Wetlands, including both marsh and peatland types, cover a significant portion of the undisturbed landscape in the oil sands region. These wetland areas are extremely important to the regional First Nations and Métis communities. Aboriginal peoples use wetlands for subsistence hunting, trapping, and food and medicinal plant collection , as well as for spiritual and cultural purposes. The desire and need to maintain their culture is closely linked to the ability to practice traditional activities even if they are not living a completely traditional life style.

Wetlands support a significant number of plant and animal species that are integral to the traditional lifestyle. Appendix I provides information on traditional plant species found in the various wetland types in the oil sands region.

2.5.2 Subsistence Activities

Aboriginal people in the oil sands region still rely heavily on hunting and fishing to supply a part of their diet. Wetlands provide habitat for species used by aboriginal people. Fish from marsh wetlands also supply food for sled dogs, an important consideration for Fort Chipewyan aboriginal peoples. Food and medicinal plants are collected throughout the region, often in the same areas in summer that are used for trapping in winter. Berries and herbs that grow in wetlands are very important for food, while medicinal plants are collected from traditional wetland areas. Appendix I lists plant species of importance to traditional users.

Trapping continues to be an important economic and cultural activity in northeastern Alberta. Trap lines are often handed down from generation to generation or assigned to others and improvements purchased. Traplines provide year round opportunities to hunt, trap, fish, collect plants and instruct the younger generation in traditional ways.

2.5.3 Cultural Heritage

The importance of maintaining their culture cannot be overstated for many of the aboriginal people of the region. This includes having enough opportunities to teach succeeding generations how to live off the land and to give them pride in their heritage. Since wetlands, in particular peatlands, form such a significant part of the region they also are part of the cultural and spiritual training. Wetlands established on the reclaimed landscape will take time to achieve the ecological health and balance necessary to be used in support of cultural activities. This fact will need to be recognized by all participants in the development of new wetlands (i.e., wetlands will provide opportunities but the results will take time).

The elders and the people actively involved in traditional pursuits have a valuable store of knowledge regarding the habitat preferences of species of importance to them as well as an understanding of how natural systems function. This knowledge will be very helpful in designing wetlands in the reclamation landscape. This information may be shared by developing partnerships with community elders and representatives and working with them in the field on an on-going basis during baseline studies, development, reclamation planning and reclamation implementation.

2.5.4 Traditional Use of Reclaimed Wetlands

The change from a primarily peatland landscape to a primarily upland landscape with some marsh wetlands will change the mix of species, both plant and animal, available for traditional use. While some species will not be available to the same extent as before (e.g., bog cranberry) there will be opportunities to enhance the occurrence of other species. Consultation with the various local aboriginal communities will be helpful in maximizing these opportunities wherever possible.

The types of wetlands that will be created on reclamation areas do not include the peatlands that are traditionally used by aboriginal peoples. As a result, aboriginal peoples view the conservation of peatlands in other areas of the oil sands region as critical to their interests. While the uses typically associated with peatlands will not be available, the marsh wetlands created in the reclaimed landscape should eventually provide some uses that were present in the pre-development wetlands. The types of plant species that may be found in the reclamation area wetlands are listed in Appendix I under the non-peatland wetland types. The outcome of research on the reclamation wetlands will confirm whether all of the listed species will eventually be found in the reclamation wetlands.

The other issue that must be resolved for the reclamation wetlands before their full use by aboriginal peoples is re-established relates to contaminant levels in the plants and animals. The wetlands research will help confirm whether the reclamation wetlands will produce plants and animals that have levels of contaminants such that their use for consumption by aboriginal peoples will be acceptable.

2.6 Key References

There are literally thousands of scientific and engineering papers on natural and constructed wetlands. Research continues to generate additional information each year. As a result, books or reports that attempt to summarize, synthesize and integrate the large amount of literature have an important role to play in wetland planning, construction, operation, maintenance and assessment. In this respect, there are a number of good books available on wetland ecology and wetland design. They are necessary references for the creation of wetlands in the oil sand regions recognizing that the information has to be applied and adapted to oil sands mining goals and methods. Some key references are as follows:

Mitsch, W. J. and J. G. Gosselink. 1993. Wetlands (Second Edition). Van Nostrand Reinhold, New York. 722p. Mitsch and Gosslink provide a comprehensive discussion of the wetland environment (hydrology, biogeochemistry, biology, wetland ecosystems), inland wetland ecosystems (including freshwater marshes, northern peatlands and riparian systems) and the management of wetlands (including wetland creation and restoration). The book provides a comprehensive reference for scientists, engineers and planners involved in the ecology and management of wetlands.

Kadlec, R. H. and R. L. Knight. 1996. Treatment Wetlands. Lewis Publishers, Boca Raton. 881p. Kadlec and Knight have authored what is recognized as one of the major references on the use of wetlands to improve water quality. There is extensive discussion of wetland structure and function, the effects of wetlands on water quality, wetland project planning and design, wetland treatment system establishment and operation, and wetland case histories. The 27 chapters in this book provide comprehensive information on water treatment wetlands.

Moshiri, G. A. (Editor). 1993. Constructed Wetlands for Water Quality Improvement. Lewis Publishers, Boca Rotan. 632p. Moshiri, as editor, has assembled 68 papers that deal with general considerations in constructed wetlands, engineering, subsurface systems, chemical processes, point and non-point sources, vegetation considerations, industrial applications, small systems and case studies. The book emphasizes the importance of scientific foundations for constructed wetlands and the need to incorporate some of fundamental operational characteristics of natural systems into the design, operations and expectations of constructed wetlands.

Eastlick, K. 1993. Wetlands Wastewater Treatment – A Literature Review of Natural and Wetlands Ecotechnologies for Improving Quality of Runoff, Municipal Sewage and Industrial Wastewater. Wetlands Design Group, Calgary, Alberta. Eastlick has conducted a literature review to evaluate biological, physical and chemical processes of wetlands and related treatment systems design procedures. Eastlick notes that limited work with ecotechnology in cold climates requires implementation of local projects to develop western Canadian experience and design adaptations. The literature review includes discussions related to contaminant removal processes, hydrology considerations, wetland and natural wastewater treatment processes, potential applications for wastewater treatment, and wetlands treatment and research needs.

3. OBJECTIVES OF THE GUIDELINE FOR VARIOUS USERS

The guideline will be used by operators, regulatory agencies and the public, in particular, aboriginal communities (Figure 3.1). The objectives of the guideline for the various users include:

1. General Objectives
    - to promote understanding of wetland establishment and successful reclamation
    - to provide for the sharing of knowledge among operators, government, consultants, academic institutions, and the public, in particular the aboriginal community
    - to foster the basis for communication among oil sands developers
    - to prioritize and focus research needs

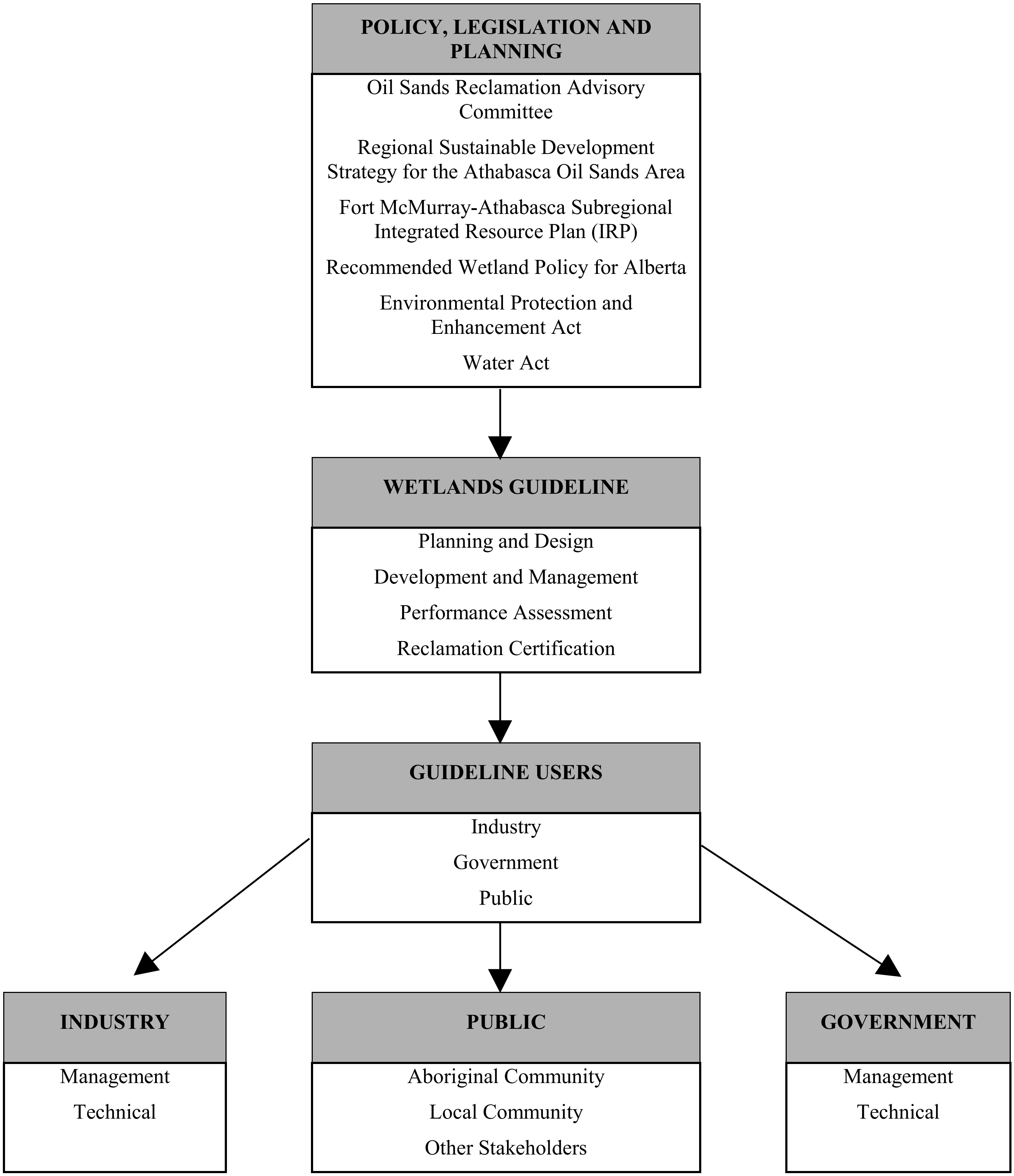
2. Objectives for Managers
    - information at the broad conceptual level regarding wetland reclamation
    - information for planning and design that will ensure a proposed wetland will:
        - meet government policy and regulatory requirements
        - meet end land use requirements
        - achieve certification
    - information for performance assessment and evaluation of risk and potential failure modes, including the need for monitoring and adaptive management
    - information to assist in the development of wetland reclamation teams (i.e., recognition of the need for interdisciplinary teams and the disciplines involved at various stages in the establishment of wetlands)
    - information regarding the need for and involvement of aboriginal communities in all stages of wetland reclamation, from the planning and design stage through to evaluation of the reclaimed wetland

3. Objectives for Technical Staff
    - provision of a wetland framework, including technical information, that will support all the stages of the wetland reclamation process (i.e., planning and design, development and management, performance assessment, certification)
    - provision of technical information at both the wetland level and the landscape level to support wetland reclamation
    - direction on what needs to be done to construct a particular type of wetland

4. Objectives for Regulatory Agencies
    - description and clarification to operators and the public regarding government policy, legislation and expectations with respect to wetland reclamation
    - information that will assist government staff in providing advice to operators, reviewing applications, and evaluating wetland reclamation

5. Objectives for Aboriginal Communities
    - recognition of the value of wetlands to aboriginal communities
    - recognition of the knowledge that aboriginal communities possess with respect to wetlands and what constitutes a good or useful wetland
    - recognition of the need for consultation with aboriginal communities in all stages of wetland reclamation
    - opportunity to provide traditional knowledge and aboriginal needs as part of wetland planning

Figure 1.2. Use of the guideline



4. WETLAND DEVELOPMENT APPROACH

4.1 Introduction

Section 4 of the guideline provides the basic development approach for creating a variety of wetland types on a reclaimed landscape. It discusses key functions and values of wetlands, landscape components, the general approach to wetland development, and the establishment of specific wetland types. The format includes tables, flow charts and wetland planning sheets.

4.1 Introduction
- functions and values of natural wetlands and reclaimed wetlands
- types of water releases from landforms

4.2 Landscape Components
- landscape level design factors and table on landscape key issues
- closure planning and overview of oil sands mining landforms

4.3 General Approach to Wetland Development
- wetland types in the reclaimed landscape
- spatial and temporal considerations
- location of wetlands in the reclaimed landscape
- key design issues (hydrology, physical, biological, chemical, nutrients, traditional use)
- hydrology and water quality as key determinants in wetland reclamation

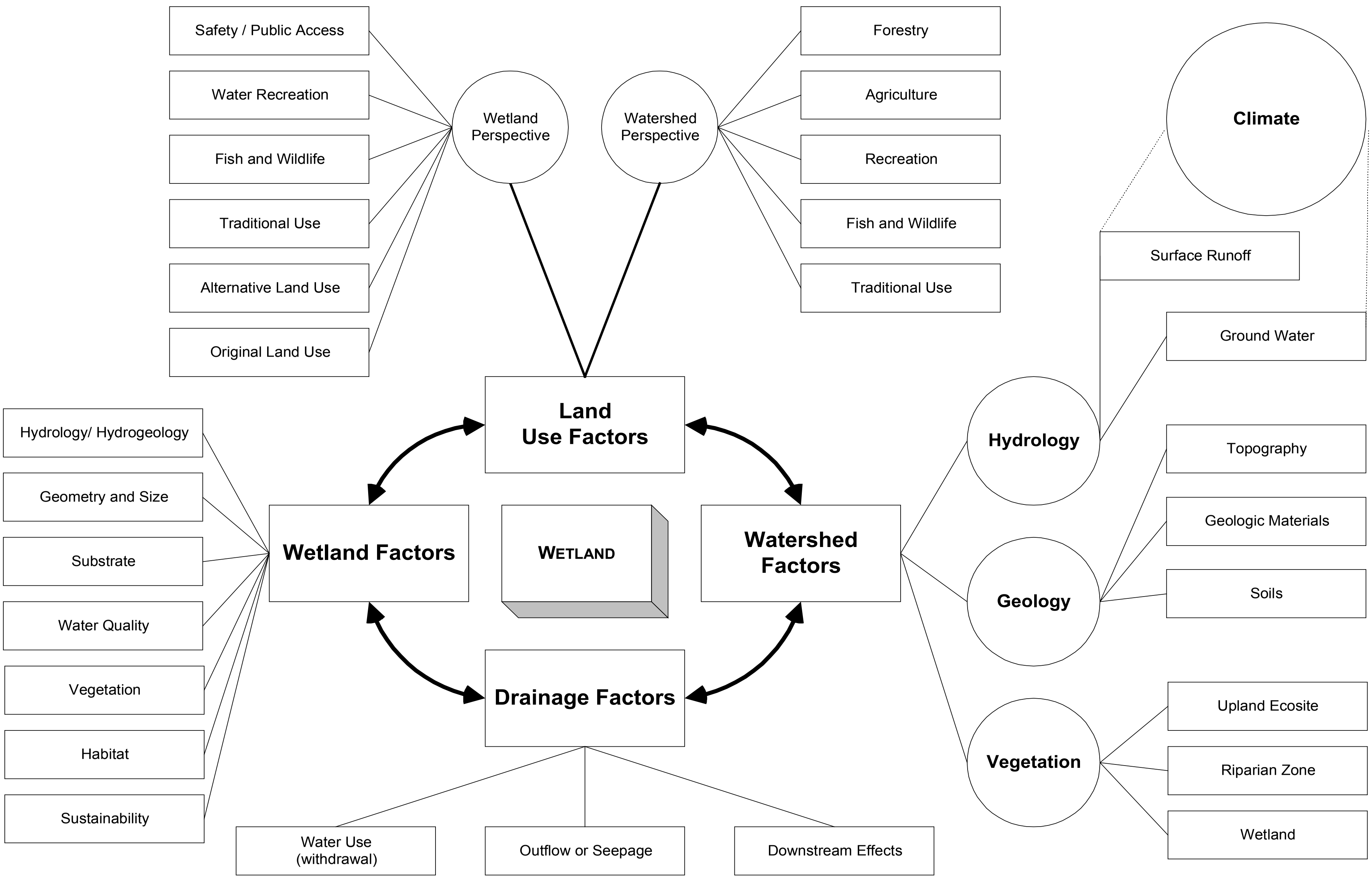
4.4 Establishment of Specific Wetland Types
- Wetland Management Flow Chart and information package for each wetland type
  - general description to provide an overview, rationale, and comments
  - development flow chart to outline the design and implementation process
  - key issues checklist and selected design recommendations
  - development approach sheet (a form to be used to design the wetland)

The design of wetlands on a reclaimed landscape will be determined by a variety of factors (Figure 4.1), including wetland features (e.g., hydrology, substrate, habitat), land use at both the wetland and watershed level (e.g., recreation), watershed characteristics (e.g., hydrology) and drainage regime (e.g., downstream effects). There can be a fair degree of control over some factors (e.g., geometry) while others will have less control (e.g., hydrogeolgy). The ability to influence the various factors needs to be considered with the most effort directed at parameters that make the most difference and are subject to the most control.

Wetland creation must be an interdisciplinary team effort. It will require a variety of engineering and environmental disciplines (e.g., mine planners and engineers; water management engineers; hydrologists; hydrogeologists; water quality scientists; wetland ecologists; microbiologists; botanists; wildlife, waterfowl and fisheries biologists, etc.), as well as assistance from those with traditional knowledge.

As previously noted, the guideline provides an approach to wetland development. The development approach will need to be revised and updated as new knowledge is gained.

Figure 4.1 Factors that determine the design of a wetland on a reclaimed landscape



4.1.1 Functions and Values of Natural Wetlands

The functions and values of Alberta's wetlands are documented in Westworth (1993):

> *"Wetland functions do not always result in values that are tangible and easily measured. The production of animal pelts or wild rice are measurable values of wetlands function, whereas the value of wetlands function in educational and scientific research is difficult to quantify. Wetlands may have no immediately discernible value because of the remoteness of a wetlands region, or because the wetlands function does not have a clear market value. Some wetland benefits may represent values held in trust for future generations. Examples may include wetland peat deposits as stores of potential energy supply; or wetlands that represent future recreational, aesthetic and economic benefit for Albertans."*

Westworth grouped wetlands functions into five categories:

1. **Ecology:** habitat for all types of microscopic, invertebrate and vertebrate animals, microscopic and macroscopic plants.

2. **Hydrology:** flood buffering and water storage, groundwater discharge and recharge, surface water flow augmentation, influences on the climatic regime.

3. **Water Quality:** modification of chemical, sedimentary and biological water constituents; changes in dissolved oxygen, pH and mineral composition.

4. **Economic:** production of economically important flora and fauna, value to the tourism industry, value to farming and agriculture, production of agricultural crops.

5. **Heritage:** recreational value, benefits for education and scientific research, value to future generations.

For aboriginal communities, wetlands provide important economic and heritage values. Economic values include production of animal species for subsistence hunting, fishing and trapping, as well as plant species for food. Heritage values include provision of traditional medicines, as well as cultural and spiritual continuation through maintenance of particular species, areas and activities. In addition, wetlands provide opportunities for educating succeeding generations in traditional lifestyles.

4.1.2 Functions and Values of Reclaimed Wetlands

While the predominant pre-disturbance peatlands cannot be replaced on the reclaimed landscape, the creation of marshes and shallow open water areas will provide the basis for a diverse, but different, habitat. Marshes are relatively rare in the oil sands region and make up only 7% of Alberta's total wetlands (AWRC 1994).

Although marshes established on the reclaimed landscape will have different ecological and end land use characteristics compared to the predominant peatland ecology of the pre-development landscape, they can be designed to perform functions that are typical of natural wetlands. In this context, the key functions and values of wetlands in the reclaimed landscape are to:

- maintain an acceptable water quality;
- develop a sustainable hydrological regime;
- sustain viable habitat for aquatic and terrestrial animals;
- provide opportunities for traditional land use including spiritual activities, subsistence hunting, collecting food and medicinal plants, trapping and cultural continuation.

Economic and heritage goals should be brought into the design and will be achieved by attaining these primary functions; however, they have not been considered directly in the development approach for the wetlands. A recreation assessment of Syncrude’s Leased Lands provides some consideration on how wetlands could be used as a recreational resource (Syncrude 1992). Ongoing participation by First Nations and Métis people in the wetlands planning and reclamation process will strengthen the opportunities for reclaimed wetlands to provide economic and heritage values to aboriginal communities.

4.1.3 Water Releases from Landforms on the Reclaimed Landscape

Wetlands will be necessary on the reclaimed landscape to establish the natural functions of the removed fens and bogs (e.g., flood control, wildlife habitat). In addition, they will be needed as self-sustaining, environmentally acceptable treatment systems for process-affected waters. These waters arise during operational or reclamation/closure phases of an oil sands mine. The types and characteristics of water releases have been described by the Oil Sands Water Release Technical Working Group (OSWRTWG 1996) for both operational and reclamation/closure scenarios as shown in Table 4.1.

Table 4.1. Types and characteristics of oil sands water releases

Operational Water Releases Types	Reclamation Water Releases Types
Consolidated/composite tailings release water = CT release water	Fine tails release water (i.e., into capping layer in wet landscape scenario)
Collected seepage waters from dykes and structures	Runoff and drainage from reclamation units: • Sand dykes and dumps • CT deposits • Fine tailings deposits • Coke piles, plus other waste areas • Wetland treatment systems • Overburden dumps
Mine drainage (runoff, dewatering)	
Upgrading wastewaters (cokers, upgrader)	
Cooling waters	
Sewage treatment system wastewaters	
Others – undefined new process waters	
	Reclaimed lease groundwaters

Operational Water Releases Characteristics	Reclamation Water Releases Characteristics
Point source "streams" or facility discharges	Non-point source diffuse waters which may be directed through wetlands and lakes
Discharged during operations or shorter timeframe	Slow release over large areas for extended timeframe (i.e., extending past closure and certification)
Controllable	Non-controllable
Treatable in managed treatment systems	Altered by natural systems or constructed wetlands
Can be compared to discharge limits or ambient water quality guidelines (if available)	Water quality guidelines may not directly apply or be available for all parameters
Potential to cause regional off-site impacts	Primarily an on-site water management issue; part of maintenance-free reclamation landscapes

Wetlands can be used to improve the water quality of released waters. Principal environmental constituents of concern are: hydrocarbons, ammonia, metals, and naphthenic acids. Saline water with elevated levels of sulphate (from the calcium sulphate used to aid the consolidation of tailings) will also be released from CT landforms and sand storage areas, as well as from some overburden dumps (if there are high salt levels in the subsurface geology).

The use of wetlands to treat process-affected water is a relatively new biotechnology compared with conventional treatment systems (Hamilton et al. 1993); therefore, correspondingly new approaches will be required by regulatory agencies (Gulley and Nix 1993). For example, criteria are needed for effluent quality as well as for ecological acceptability (i.e., wildlife habitat). Alberta Environment has developed a policy (AEP 1995a) and procedures manual (AEP 1995b) for industrial effluent limits which can be used to deal with water discharges from water treatment wetlands receiving process-affected waters. The development of treatment wetlands has environmental implications, both with respect to possible adverse impacts (e.g., bioaccumulation of chemicals, effects of salinity) and ecological benefits (e.g., potential for increased waterfowl habitat, increased plant productivity), For this reason, pilot-scale treatment wetlands are needed to provide more refined design criteria than are given in this guideline and to assess the relative benefits and impacts of these wetlands.

Surface-flow water treatment wetlands described in this guideline have been researched for treatment of process-affected reclamation water releases on the surface of reclaimed landscapes (Nix 1995a,b). However, treatment of operational water releases using the same developmental approach is possible. For example, a water treatment wetland on, or adjacent to, a CT landform could be used during mine operations to treat process-affected water. A discharge could be allowed if it complied with Alberta Environment's protocols for release, otherwise it would have to be used as recycle water. Subsurface flow wetlands might be useful for the treatment of operational waters over the short-term. Research at Suncor, using biological filters to simulate subsurface wetlands, has shown that ammonia and acute toxicity can be removed from process-affected waters in a matter of days rather than the weeks required for surface flow wetlands (Bishay and Nix 1996). Subsurface flow wetlands would likely not be suitable in the long-term since they are more expensive to construct and require more maintenance (Kadlec and Knight 1996).

4.2 Landscape Components

4.2.1 Introduction

Wetlands perform major functions in landscapes including provision of habitat for fish and wildlife, catchment of fertile sediment, purification of runoff, recharge of aquifers, biogeochemical transformation of nutrients such as carbon, nitrogen, sulphur and phosphorus (including greenhouse gases), and exchanges of chemicals, nutrients and organic matter with associated aquatic and upland ecosystems (Odum 1983). In addition, wetlands convey water across the landscape.

The Boreal Forest Region supports a large diversity of wildlife including at least 236 bird species and 43 mammal species (Westworth 1993). Many of these species, as well as amphibians, are dependent on wetlands. Wildlife utilize a diversity of wetland types and associated terrestrial environments to satisfy basic habitat requirements related to food, cover and reproduction. Wetlands with different habitat attributes may be required during the annual life cycle of many species. For example, waterfowl utilize a diversity of habitat types ranging from temporary, shallow flooded wetlands to large lakes for migration, breeding, brood rearing and moulting. Similarly, migrant and breeding shorebirds will opportunistically utilize a variety of boreal wetlands types.

Wetland planning and design must recognize the interrelationship between the wetland being established and the overall landscape. This requires consideration of the landforms that are created during oil sands mining and the various design factors that operate at a landscape level.

4.2.2 Closure Planning in Relation to Wetland Establishment

Closure plans describe how an oil sands operation will look after reclamation. A closure plan considers the potential or optional end land uses, integration with surrounding mining operations, maintenance requirements and cost (Oil Sands Mining End Land use Committee 1997). Landscape design must achieve the intended post-mining land capabilities for the end land uses of the reclaimed area. Closure plans must integrate the design criteria for all the intended land uses.

The present guideline for wetland establishment does not prescribe the overall percentage, type or distribution of wetlands at a particular oil sands operation. As noted in Section 2.4, these matters are dealt with site specifically through the regulatory approvals operators must obtain and the regional coordinating role provided by the Oil Sands Reclamation Advisory Committee.

The key point for closure planning is that an integrated final landscape should be conceptually developed at the beginning of the mine planning process. The closure plan will require wetlands as an integral part of the reclaimed landscape. This means that wetlands cannot be designed and developed in isolation from the rest of the landscape. Upland areas, surface drainage systems, and wetlands are all part of an integrated landscape.

4.2.3 Overview of Oil Sands Mining Landforms

The oil sands mining process creates several types of landforms. Overburden materials are the first upland substrates to be placed, followed by tailings sand and finally CT deposits. These deposits are placed where feasible and most economical based on consideration of mining operations, overall mining plans, need for structures, transportation costs, environmental issues and closure plans. The optimum plan is to minimize the “reworking” of materials once placed, although minor re-shaping is routinely done. Dyke walls and storage piles have strong slopes (25 to 35%; 14° to 19°) with steepness governed by geotechnical stability, resistance to erosion and end land use considerations. Storage pile tops and CT surfaces are level or gently undulating. Some re-shaping of all these surfaces may be undertaken to create topographic variation and a more “natural” appearance.

Once in place, these substrates are capped with one or two layers of soil materials. For example, peat-mineral mix material or direct placement material is placed as one layer (“coversoil”) on overburden or tailings sands. In two layer placement, a layer of suitable subsoil is placed first then covered with a layer of peat-mineral mix coversoil. The quality, depth, and extent of replaced soils are designed to meet “equivalent land capability” as compared to pre-disturbance conditions. The *Land Capability*

Classification for Forest Ecosystems in the Oil Sands Region (Leskiw 1998) is used to rate both pre-disturbance and reclamation capability and also for reclamation planning.

After landscape contouring and soil placement, the uplands are revegetated to meet requirements of the targeted end land use. To date, vegetation communities have been successfully established to support forest ecosystems, including tree, shrub, grass and forb components. Further information regarding forest vegetation establishment is provided in the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (Oil Sands Vegetation Reclamation Committee 1999).

Designing wetlands involves planning material placement to create the wetlands rather than building the wetlands on previously level areas. Wetlands can be established in depressions in the reclaimed landscape if the surrounding uplands contribute sufficient water. Wetlands are more efficiently created by "leaving" depressions during material placement rather than by "excavating" depressions in the landscape. Hence, it is necessary to plan the final landscape in advance so that desired wetland types, configurations, and patterns can be established in a cost effective and ecologically sustainable manner.

Table 4.2 summarizes the following key landscape issues in wetland planning, including design considerations:

1. watershed configuration (upland to wetland ratio)
2. surface drainage
3. sustainability
   a) overburden
   b) tailings sand
   c) CT deposits
4. landscape factors
   a) slope angle
   b) slope length
   c) aspect
5. soil factors
   a) overburden (topsoil, upper subsoil, lower subsoil)
   b) tailings sand (topsoil, upper subsoil, lower subsoil)
   c) CT deposits (topsoil, upper subsoil, lower subsoil)
6. vegetation

Appendix C provides more detailed discussions of landscape factors.

Table 4.2. Landscape key design issues in wetland planning

Design Factor	Relative Importance	Degree of Control	Parameter Ranges and Probability of Success		
			High	**Medium**	**Low**
Watershed Configuration **Upland to Wetland Ratio**	High	High	> 8:1 (permanent)	Ratio 2:1 to 8:1 (seasonal)	< 2:1 (temporary)

Importance/Relevance
• a sufficient area of upland is required in the watershed for stable, permanent wetland development within the reclaimed landscape
• the characteristics of the upland affect the amount of runoff and potential for wetland development, as well as runoff water quality
			Design Considerations
			• catchment area : wetlands ratio should be a minimum of 5:1 depending on substrate permeability; that is, the maximum area of a wetland should be about 20% of the catchment landscape to sustain water levels
			• slopes: steeper upland slopes with an integrated network of watercourses yield more runoff, but also have a higher erosion risk
			• landform materials vary as to soil hydrologic group (runoff potential) and rate of groundwater flow:
			  ◦ overburden: medium to high runoff potential, low rate of groundwater flow
			  ◦ tailings sand: low runoff potential (with coarse textured subsoil layer) to medium runoff potential (with fine textured subsoil layer), high rates of groundwater flow
			  ◦ CT deposits: low to medium runoff potential, medium rates of groundwater flow		

Surface Drainage and Groundwater	High	High	> 80% of land surface connected to drainage system	Percent connected 50 to 80% of land surface connected to drainage system	< 50% of land surface connected to drainage system
Importance/Relevance • well developed drainage patterns increase runoff and reduce groundwater recharge • "closed" basins tend to create temporary wetlands with considerable water level fluctuations • "closed" basins tend to increase groundwater recharge and raise the water table • "closed" basins may increase subsidence in overburden materials and CT deposits			**Design Considerations** • create a landscape that has a good surface drainage network in all basins so that surface waters will be moved off the landscape rather than being retained and moving into underlying materials • determine position of water table and location within the groundwater regime (recharge area, intermediate area or discharge area) • vegetative cover – generally runoff decreases as the vegetative cover increases and the landscape matures • to drain side slopes, create several small drainage courses rather than a few large ones		

Design Factor	Relative Importance	Degree of Control	Parameter Ranges and Probability of Success		
			High	**Medium**	**Low**
Sustainability/Evolution	High	Low	Stable, non-eroding landscape	Stability Intermediate stability and erosion	Unstable slopes, severe erosion

Importance/Relevance	Design Considerations
OVERBURDEN **Importance/Relevance** • overburden comprised of glacial materials is considered to be fairly stable on slopes and subsidence is minimal • oily overburden materials may harden if exposed and allowed to dry • bedrock derived overburden is subject to subsidence, slumping and slope failure • some overburden (e.g., Clearwater Formation) is saline (high in soluble salts) and sodic (high in exchangeable sodium); seepage waters from these materials may be saline and sodic	**Design Considerations** • place soil capping on overburden as soon as possible to prevent hardening of overburden • subsidence will likely occur and create some opportunistic wetlands (“closed” basins) • design gentle slopes to ensure stability • maximize surface runoff and drainage to minimize groundwater recharge and build up of a water table • monitor opportunistic wetlands that will likely develop and consider providing surface drainage • place appropriate soil capping depth over saline overburden • consider seepage water quality in relation to wetland establishment
TAILINGS SAND **Importance/Relevance** • tailings sand is a nutrient poor medium with low inherent moisture retention • tailings sand requires amendments of organic matter and clay to improve moisture supply, nutrient availability and retention • tailings sand is potentially subject to high wind and water erosion • seepage waters from tailings sand deposits are process-affected	**Design Considerations** • add a peat/mineral mix coversoil • minimize gully erosion especially at the toe of slopes • minimize wind erosion of exposed areas • maintain good vegetation cover (grass or trees) • avoid clear-cut logging on slopes > 20 % • consider seepage water quality in relation to wetland establishment
CT DEPOSITS **Importance/Relevance** • CT is comprised of wet, sandy, oily, saline materials; the surface dries and forms a stable crust, however, settling and drying of lower materials will take decades; some subsidence and instability is expected. • seepage waters from CT deposits are process-affected with high salt contents	**Design Considerations** • place soil capping on CT deposits as soon as possible • subsidence will likely occur and create some opportunistic wetlands (“closed” basins) • maximize surface runoff and drainage to minimize groundwater recharge and build up of a water table • monitor opportunistic wetlands that will likely develop and consider providing surface drainage • consider seepage water quality in relation to wetland establishment

Design Factor	Relative Importance	Degree of Control	Parameter Ranges and Probability of Success		
			High	**Medium**	**Low**
Landscape Factors **a. Slope Angle**	High	High	< 10%	Slope Angle 10 to 30%	> 30%
Importance/Relevance • the steepness of side slopes of overburden disposal sites affects the amount of erosion and potential sedimentation into wetlands • steeper slopes have higher potential for geotechnical instability, erosion and sedimentation			**Design Considerations** • design a variety of slopes within a watershed to spread runoff peaks • avoid developing wetlands at the base of steep slopes • minimize slope angles bordering wetlands • consider upslope geotechnical stability when placing wetlands near dyke structures and waste dumps, especially when saline or sodic materials are present		
b. Slope Length	High	High	< 50 m	Slope Length 50 to 200 m	> 200m
Importance/Relevance • the length of side slopes of overburden disposal sites affects the amount of erosion and potential sedimentation into wetlands • longer slope lengths have higher potential for erosion and sedimentation			**Design Considerations** • design a variety of slope lengths within a watershed to spread runoff peaks • design depositional areas below the toe of slopes to accumulate sediments to prevent them from entering wetlands • minimize slope lengths bordering wetlands		
c. Aspect	Low	High	Diverse Aspects	Aspect Single Aspects	N/A
Importance/Relevance • aspect of slopes > 20 % affects the soil moisture regime, runoff potential and timing of runoff; south and southwest slopes are drier, generate less runoff and snow melt occurs earlier in spring			**Design Considerations** • design watersheds having a variety of aspects to stagger runoff peaks and minimize water level fluctuations		

Design Factor	Relative Importance	Degree of Control	Parameter Ranges and Probability of Success		
			High	**Medium**	**Low**
Upland Soil Factors – Land Capability Class	High	High	1 & 2	Capability Class 3	4 & 5
OVERBURDEN					
Topsoil (0 to 20 cm) **Importance/Relevance** • the operational replacement of 15 to 20 cm of coversoil consisting of a peat-mineral mix enhances infiltration, vegetation growth and minimizes erosion • direct placement of mineral material increases runoff and erosion • the depth of soil replacement affects the rate and type of infiltration, runoff characteristics, timing of flow and erosion			**Design Considerations** • place peat-mineral mix coversoil on overburden, or on subsoil over overburden		

Upper Subsoil (20 to 50 cm)
Importance/Relevance
• a "clean" (non-saline/non-sodic) subsoil is desirable at least to 50 cm
• coarse-textured soil capping materials will increase infiltration into the soil profile and increase the amount of groundwater recharge, but decrease the amount of runoff
• fine-textured soil capping materials will decrease infiltration into the soil profile and decrease the amount of groundwater recharge, but increase the amount of runoff
			Design Considerations
			• two types of soil profiles are currently constructed on overburden
			  • peat-mineral mix coversoil over overburden
			  • peat-mineral mix coversoil over clayey subsoil over overburden		

Lower Subsoil (50 to 100 cm) **Importance/Relevance** • may be same material as upper subsoil • Clearwater Formation is highly saline and sodic and will adversely affect wetland development in terms of water quality and geotechnical stability in overburden disposal sites containing this material • due to dispersion of clays by high levels of sodium, the permeability of the material is reduced, thus reducing the amount of groundwater recharge and increasing the amount of interflow and runoff • high sodium concentrations in the overburden elevate the amount of soluble salt moving through the material and potentially discharging into wetlands • the Clearwater Formation is sedimentary and material subsides after re-placement and wetting resulting in sinkholes in the reclaimed landscape			**Design Considerations** • determine the optimum depth of soil capping material to balance runoff, Available Water Holding Capacity (AWHC) of the soil profile and depth of quality root zone • sinkholes may provide depressions where opportunistic wetlands may develop		

Design Factor	Relative Importance	Degree of Control	Parameter Ranges and Probability of Success		
			High	Medium	Low
Upland Soil Factors – Land Capability Class	High	High	1 & 2	Capability Class 3	4 & 5

Design Factor	Parameter Ranges and Probability of Success
TAILINGS SAND **Topsoil** (0 to 20 cm) **Importance/Relevance** • the operational replacement of 15 to 20 cm of coversoil consisting of a peat mineral mix enhances infiltration, vegetation growth and minimizes erosion • direct placement of mineral material increases runoff and erosion • the depth of soil replacement affects the rate and type of infiltration, runoff characteristics, timing of flow and erosion	**Design Considerations** • place peat-mineral mix coversoil on tailings sand, or on subsoil over tailings sand

Upper Subsoil (20 to 50 cm)
Importance/Relevance
• “clean” (non-saline/non-sodic) subsoil is desirable to at least 50 cm
• coarse-textured soil capping materials will increase infiltration into the soil profile and increase the amount of groundwater recharge, but decreases the amount of runoff
• fine-textured soil capping materials will decrease infiltration into the soil profile and decrease the amount of groundwater recharge, but increase the amount of runoff
	Design Considerations
	• three main types of soil profiles are currently created on tailings sand
	  • peat-mineral mix coversoil over tailings sand
	  • peat-mineral mix coversoil over sandy subsoil over tailings sand
	  • peat-mineral mix coversoil over clayey subsoil over tailings sand

Lower Subsoil (50 to 100 cm) **Importance/Relevance** • may be same material as upper subsoil or tailings sand	**Design Considerations** • determine the optimum depth of soil capping material to balance runoff, Available Water Holding Capacity (AWHC) of the soil profile and depth of quality root zone
CT DEPOSITS **Topsoil** (0 to 20 cm) **Importance/Relevance** • the operational replacement of 15 to 20 cm of coversoil consisting of a peat-mineral mix enhances infiltration, vegetation growth and minimizes erosion • direct placement of mineral material increases runoff and erosion • the depth of soil replacement affects the rate and type of infiltration, runoff characteristics, timing of flow and erosion	**Design Considerations** • place peat-mineral mix coversoil on CT, or on subsoil over CT • place sandy textured subsoil directly on CT to increase infiltration, or fine textured subsoil to increase run off

Design Factor	Relative Importance	Degree of Control	Parameter Ranges and Probability of Success		
			High	**Medium**	**Low**
Upland Soil Factors – Land Capability Class	High	High	1 & 2	Capability Class 3	4 & 5

Upper Subsoil (20 to 50 cm)
Importance/Relevance
• a "clean" (non-saline/non-sodic) subsoil is desirable at least to 50 cm
• coarse-textured soil capping materials will increase infiltration into the soil profile and increase the amount of groundwater recharge, but decrease the amount of runoff
• fine-textured soil capping materials will decrease infiltration into the soil profile and decrease the amount of groundwater recharge, but increase the amount of runoff
•
			Design Considerations
			• three types of soil profiles are currently proposed on CT deposits
			  • peat-mineral mix coversoil over CT
			  • peat-mineral mix coversoil over overburden over CT
			  • peat-mineral mix coversoil over tailing sand over CT		

Lower Subsoil (50 cm to 100 cm) **Importance/Relevance** • may be same material as upper subsoil, or CT			**Design Considerations** • determine the optimum depth of soil capping material to balance runoff, AWHC of the soil profile and depth of quality root zone • subsidence may provide depressions where opportunistic wetlands may develop		

Design Factor	Relative Importance	Degree of Control	Parameter Ranges and Probability of Success		
			High	**Medium**	Low
Upland Vegetation Cover	Medium	High	> 90%	Cover 60% to 90%	< 60%

Importance/Relevance

- the type of vegetation cover on the reclaimed landscape affects the amount of erosion, sedimentation and hydrologic regime of upland areas which provide water for the developing wetlands

Design Considerations

- in the oil sands region, the following upland vegetation types represent different stages of succession towards either a herbaceous/shrub or forest community
  - bare ground (i.e., prior to revegetation)
  - annual barley cover crop and tree seedlings
  - herbaceous/shrub
  - forest
- wetland development should occur within vegetation cover types that reduce the amount of erosion and sedimentation into wetlands (Appendix C)
- the timing of upland vegetation establishment is an important consideration for timing of wetland development
  - bare ground - high erosion and sedimentation potential
  - cover crop with planted tree seedlings - moderate erosion and sedimentation control
  - herbaceous/shrub - quick (2 year) establishment and low erosion and sedimentation
  - forest – slow (5 year) establishment and low erosion and sedimentation

4.3 Wetland Development

4.3.1 Wetland Types

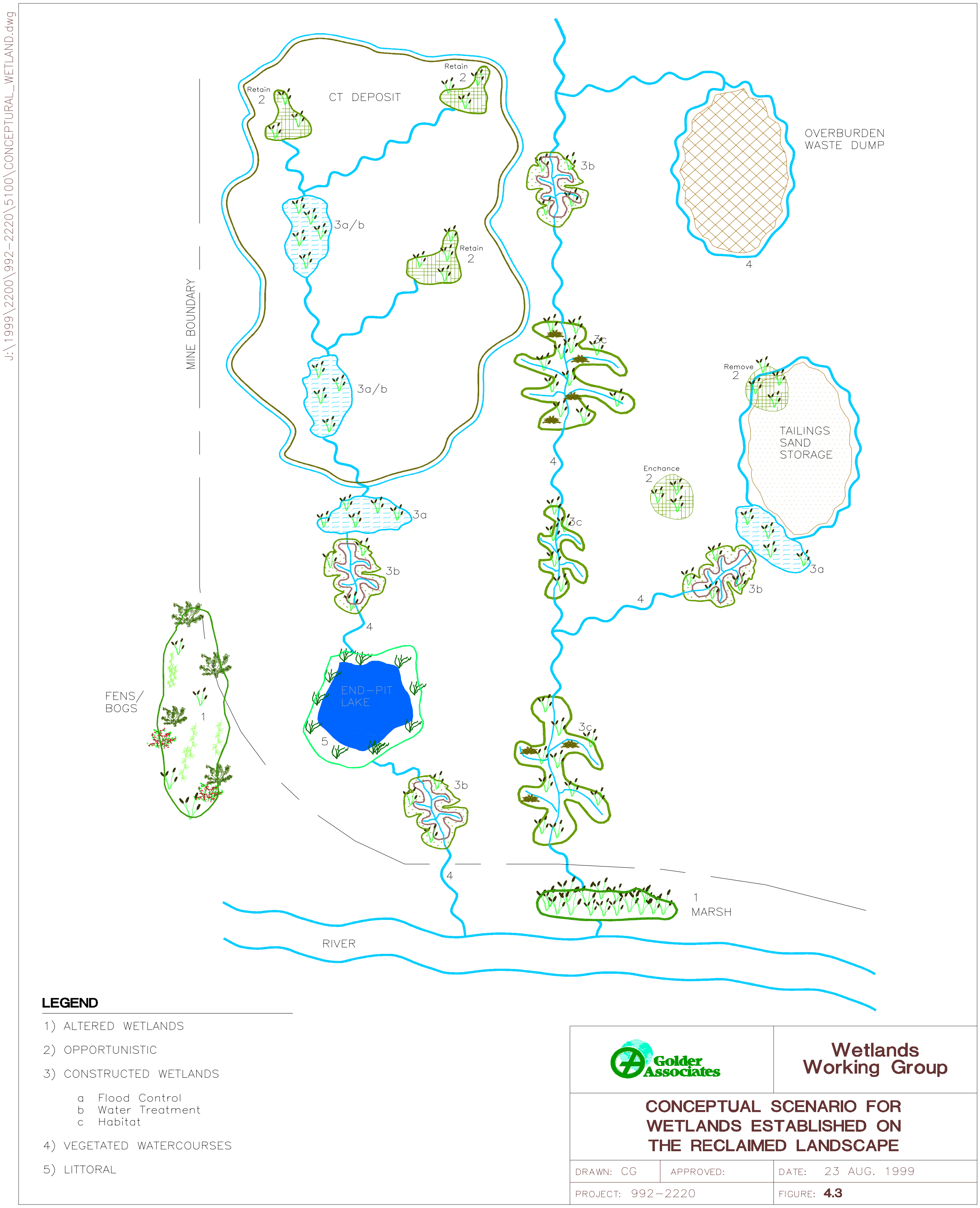
Although peatlands are the dominant natural wetland in the pre-development landscape, they will not be replaced after reclamation. This is a consequence of the substantial time required for peatlands to form, along with their specific landscape and water chemistry requirements (Vitt et al. 1996). The post-development landscape will change in terms of topography, hydrology, hydrogeology, drainage patterns, soil/sediment characteristics and water chemistry. These changes will not be conducive to peatland development. The creation of shallow marshes in the reclaimed landscape in lieu of peatlands is feasible and can be done in a manner that should provide functions and values comparable to natural wetlands. Long-term succession of marshes to peatlands should occur but will take considerable time.

Five wetland types are associated with reclaimed landscapes at oil sands mines (Table 4.3 Figure 4.3).

Table 4.3. Wetland Types on the Reclaimed Landscape

Type	Classification	Definition/Primary Function
Altered	Peatlands Marshes	• onsite and offsite wetlands not directly removed by the mining operation but potentially affected through drainage changes (e.g., catchment area), water table drawdown, etc; may have significant values that warrant conservation of the wetland • conservation and mitigation issues are the subject of EIA's specific to each mine and subsequent regulatory approvals
Opportunistic	Marshes	• wetlands that are not formally planned but arise inadvertently from depressions that form in the reclaimed landscape (i.e., settling), a rise in the water table, or impeded drainage • can provide functions related to flood control, water quality improvement and habitat
Constructed	Marshes	• wetlands designed on the reclaimed landscape for a specific primary function (other functions will co-exist)
Flood Control		• provide hydrological functions: flood control; peak flow attenuation; reduction of downstream flooding; flushing of saline waters
Water Treatment		• improve water quality through biological (e.g., biodegradation), chemical (e.g., precipitation) or physical (e.g., flushing of salts) processes; water quality could improve in terms of specific parameters, toxicity, etc.
Habitat		• provide habitat for plants, wildlife, fish
Vegetated Watercourses	Not applicable	• wetlands designed as vegetated channels on the reclaimed landscape for the purpose of conveying water to wetlands, between wetlands, and offsite • provide riparian areas that connect wetlands and provide wildlife habitat, including wildlife travel corridors
Littoral Zones	Marshes	• wetlands designed along the shores of reclaimed end pit lakes • enhance habitat functions; can also provide shoreline protection and enhance water quality (i.e., degradation of contaminants)

Figure 4.2 Conceptual scenario for wetlands established in the reclaimed landscape



4.3.2 Spatial and Temporal Considerations of Constructed Wetlands

Although each type of constructed wetland type is expected to have a primary function, other functions will exist since wetland functions are not mutually exclusive. For example, a water treatment wetland can provide habitat for some wildlife, as well a degree of flood control. Natural processes will ensure the presence of all functions to some degree. Additionally, the primary function may change over time; for example, treatment wetlands may become habitat wetlands as the volume and quality of process-affected water changes over time (e.g., seepage from CT deposits).

The present design concept for constructed wetlands is a combination of wetlands consisting of three functional "units": flood control, water treatment, and habitat (Figure 4.3). The configuration and relative size of each unit within this basic conceptual "structure" will vary depending on the need for each primary function within specific reclamation landscapes (i.e., spatial factor). Also, the relative size of each unit may depend on the period of time after mining when, for example, the need for water treatment or flood control may diminish (i.e., temporal factor).

Within this conceptual structure habitat wetlands can provide a range of habitat types such as:

1. floodplains — shrubs, sedges and grasses, nesting habitat for waterfowl and other birds;
2. shallow areas — dense emergent vegetation for wildlife/waterfowl habitat;
3. deep areas — refuge for overwintering forage fish, aquatic furbearers, etc.;
   habitat for submergent plants (high food value), cover for fish
   open water zones with enhanced aeration
4. islands — nesting sites for waterfowl and colonial nesting birds;
5. low banks — access for ungulates and other mammals;
6. high banks — denning habitat for some furbearers (e.g., muskrat, beaver) as well as other wildlife (e.g., swallows, kingfishers).

In the design concept, vegetated watercourses will serve to connect flood control and water treatment wetlands, as well as many habitat wetlands. In addition to the basic hydrological role of conveying water, they will provide valuable riparian habitat (e.g., habitat for fish and wildlife species, including travel corridors for wildlife).

4.3.3 Locations of Wetland Types on the Reclaimed Landscape

Figure 4.3 illustrates a conceptual scenario for wetlands established on the reclaimed landscape. This schematic provides a conceptual map to be used as one aid in the design of reclaimed landscapes. A brief discussion of possible locations for each wetland type is outlined below.

4.3.3.1 Altered

The location of altered wetlands will be a function of the pre-development wetland characteristics of each oil sands lease. The evaluation of their status and value, and the possible need to mitigate any adverse effects that may arise from oil sands mining, is addressed through the environmental impact assessment (EIA) process with subsequent follow-up through the EPEA approvals for specific operations, including monitoring by the operators. Altered wetlands would normally be located "offsite" (i.e., outside the mine boundary) but in some instances may be located "onsite" (i.e., within the mine boundary but not directly removed by mining). Figure 4.3 shows a fen or bog outside the mine boundary, as well as a natural marsh receiving flow from the post-mining landscape.

4.3.3.2 Opportunistic

Opportunistic wetlands might appear anywhere on the reclaimed landscape. They are not formally planned but arise inadvertently due to a combination of factors. These include differential settling of landforms, a rise in the water table or impeded drainage (groundwater or surface water). Three possible options exist depending on their value in the reclaimed landscape (discussed further in Section 4.4.3). Opportunistic wetlands could be:

1. *removed* if they present a hazard such as the potential for eroding slopes;
2. *retained* if they do not present a hazard and provide a valued function (e.g., habitat);
3. *enhanced* if: a) there is opportunity to add significant functional value either locally (e.g., fish habitat, water treatment) or for the entire landscape (e.g., terrestrial wildlife, recreation, connectivity, wildlife travel corridor), and b) they are located at lower elevations with the potential for a large enough drainage basin such that they could be sustained indefinitely.

Figure 4.3 shows an opportunistic wetland that would be removed since it formed at the base of a tailings sand storage area, one that would be retained on a CT deposit since it could provide a needed function (e.g., upstream flood control), and one that would be enhanced on a mined out area since it could add to habitat values on the reclaimed landscape.

Opportunistic wetlands may be of particular significance on CT landforms. If subsidence is substantial and uneven on CT deposits, many opportunistic wetlands may be located on these landforms. If desired, these wetlands might be enhanced or engineered to provide some measure of flood control or water treatment as "constructed" wetlands. For example, wetlands on the surface of CT landforms may be needed to treat process-affected water or CT release water such that these waters could be recycled back into the extraction process or, perhaps, discharged. Alternatively, water treatment or flood control might be needed as "pre-treatment" for downstream constructed wetlands at the toe of CT landforms.

4.3.3.3 Constructed

Constructed wetlands may be located on the surface of CT deposits to provide flood control or water treatment functions. They could be created through the method of CT placement as well as through the placement of the capping layer of sand or overburden. Alternatively, they might be created through the retention or enhancement of opportunistic wetlands (see above). The configuration and types of wetlands on CT deposits is preliminary since the rate of consolidation and dewatering of this landform is not yet confirmed.

More certainly, constructed wetlands will be located at the toe of the three major landform types. Figure 4.3 shows constructed wetlands below a CT deposit, a tailings sand storage area and an overburden waste dump. These wetlands will handle water by providing, at the appropriate location in the reclaimed landscape, some combination of the three most valued functions (flood control, water treatment or habitat). For example, all three functional types will likely be needed at the toe of sand storage areas and CT landforms since these areas may be relatively large and may seep process-affected waters for many years. Since overburden dumps are relatively smaller, downstream flood control wetlands may not be needed and the emphasis may be placed on water treatment and habitat functions. Assuming that water is adequately treated, perhaps only habitat wetlands will be required further downstream.

When water seepage rates diminish and water quality improves over time, wetlands providing combined functions may revert to smaller wetlands with habitat as their primary function. Habitat wetlands should be the primary focus at all possible sites downstream of treatment wetlands.

4.3.3.4 Vegetated Watercourses

Figure 4.3 shows that vegetated watercourses will convey water to wetlands, between wetlands and offsite to receiving systems. Watercourses enhance the value of the aquatic and terrestrial landscape by providing both aquatic habitat and riparian areas. They should be located to optimize drainage, to provide valuable travel corridors for wildlife and to connect isolated wetlands.

4.3.3.5 Littoral Zones

These wetlands will be located exclusively within end pit lakes.

4.3.3.6 Key Wetland Design Issues

The following tables identify and summarize key issues that need to be considered in the design of wetlands. These issues have been categorized as:

Hydrological (Table 4.4)

- water supply and movement are critical to wetland sustainability and function
- wetlands, by definition, must be covered with water for all or part of the year
- extensive discussion of the hydrology of reclaimed landscapes is provided in Golder (1998a)

Physical (Table 4.5)

- a number of physical attributes, some associated with the surrounding landscape, have a substantial impact on wetlands development and function
- wetlands both impact and reflect the landscape; therefore, landscape characteristics will help to shape the character and ecology of any created wetlands

Biological (Table 4.6)

- biology is the final expression, and often the most valued aspect of a wetland, and is a reflection of many factors

Chemical (Table 4.7)

- environmental constituents of concern will require treatment as process-affected waters seep out from various landforms on the reclaimed landscape (e.g., CT deposits, overburden dumps, tailings sands storage areas)
- properly designed and functioning wetlands are an appropriate passive, self-sustaining, and environmentally friendly technology for treatment of these waters over the long-term

Nutrient (Table 4.8)

- nutrients such as phosphorus (P), nitrogen (N) and carbon (C) are essential for sustainable biological systems
- the availability of nutrients will affect the rate of wetland development
- nutrients will be of particular importance in water treatment wetlands since high biological activity will enhance the degradation of environmental constituents of concern

Traditional Uses (Table 4.9)

- wetlands are important to traditional users and wetland design should address functions and values that will support traditional use

Table 4.4. Hydrological key design issues

Design Factor	Importance/Relevance	Design Considerations
1. Water depth	• water depth is a key factor in the types, distribution and abundance of plants and animals in wetlands	• providing variable water depths enhances biodiversity • if above original ground level, any ponded area should be < 2 m deep and away from earth containment structures (Golder 1998a) • if a berm or dam is associated with the establishment of a wetland, an approval under the *Water Act* is required for a berm that is 2.5 m or more in height at the downstream toe and has at least 30,000 m^3 of reservoir storage above ground
2. Catchment area (ratio of uplands:wetlands) and sustainability	• to be sustainable, water inputs from surface inflows, groundwater and precipitation must exceed water outputs from surface outflows, evapotranspiration, and discharge to groundwater, etc. • there must be a sufficient catchment area to sustain water levels in the wetland	• catchment area:wetlands ratio should be a minimum of 5:1 depending on substrate permeability; that is, the maximum area of a wetland should be about 20% of the catchment landscape to sustain water levels (in agricultural lands in Alberta the ratio varies from 100:1 to 4:1; a ratio of 8:1 provides an adequate water-shed to sustain wetlands near Saskatoon (Dr. Barbour (pers. comm.)) • large watersheds (high upland:wetland ratio) will add more phosphorus into the wetlands (i.e., from forest detritus)
3. Flood Control	• wetlands provide flood protection and supply water (Hillman 1998) • wetlands can be used to moderate water flows • flood control will reduce sediment yield downstream	• wetland size and location in the landscape will affect its capacity to attenuate floods • flood control will be strongly related to catchment properties such as slope, degree of drainage, soil, and vegetation, as well as properties of the wetland such as the area-capacity relationship • the effect of vegetation in detaining flood waters is minimal (Environment Canada 1985) • reduced peak flows will increase retention times in downstream wetlands, enhancing their water treatment capabilities • in general, when >10% of a watershed is wetlands, a substantial reduction in peak flows occurs (Johnston et al. 1990) • for flood control, the maximum recommended ratio of catchment area:wetlands is 20:1 (Golder 1998a); that is, a minimum of 5% of the catchment should be wetlands

Design Factor	Importance/Relevance	Design Considerations
4. Water Level Fluctuation and Hydroperiod	• some fluctuation in water levels is normal and can enhance wetland productivity, but extreme variations can adversely impact both plants and animals	• the impact of excessive variation is discussed in Kadlec and Knight (1996) • muskrat and beaver require relatively stable water levels
5. **Hydraulic Retention Time (HRT)**	• a primary determinant of success in water treatment wetlands since sufficient time is required for the microbial degradation of chemicals of concern	• HRT (days) = [wetland area (m^2) x depth (m)] / outflow (m^3/d) • longer retention times provide a better potential for optimum treatment; required retention times vary for each chemical of environmental concern • HRT is a mean retention time; there is an actual travel time element involved meaning that a wetland design that allows “short-cutting” will allow some water to flow through faster while other will be retained longer; short-cutting should be avoided in order to achieve the designed HRT
6. Evapotranspiration	• water loss through evapotranspiration is a key factor in wetland hydrology • most wetlands act as “water pumps”, losing nearly 2/3 of their water to the atmosphere	• a sustainable marsh requires a relatively large catchment area to provide runoff to replace water lost through evapotranspiration • marshes generally lose more water than peatlands (Mitsch and Gosselink 1993) • an average loss of water for a marsh in northern Alberta is 25 to 30 cm annually (K. Lumbis, pers. comm.) • open water evaporation is substantially higher (almost double) than marsh evaporation; therefore, the amount of open water will be a key factor in wetland design (M. Seneka, pers. comm.)
7. Connectivity	• the degree of surface water and groundwater connectivity between wetlands affects wetland development and habitat functions and values	• peatlands develop when the degree of groundwater connectivity is high (Doss 1995; Halsey et al. 1998) • connecting wetlands by using watercourse design will increase habitat value and wildlife diversity • waterfowl value of a wetland is enhanced if within 3.2 km of other wetlands (K. Lumbis, pers. comm.) or within 1.6 km of permanent waterbodies (Golet 1976) • creating wetlands in hydrologically diverse landscape locations will promote diversity (Shedlock et al. 1993)

Table 4.5. Physical key design issues

Design Factor	Importance/Relevance	Design Considerations
1. Size	• larger wetlands have more habitat diversity (Environment Canada 1985) • variation in the size of wetlands in the reclaimed landscape will provide greater habitat diversity	• wetlands of all sizes are needed to provide a variety of functions and habitats for different species • size will be primarily driven by the intended function of the wetland (e.g., flood control, water treatment, habitat)
2. Upland Sediment Yield	• the rate of infilling of a wetland from the deposition of soil from upstream erosional processes determines how long the wetland will exist (marshes naturally infill and evolve into grasslands and forests or peatlands over time) • high rates of sediment yield will decrease wetland volume and hydraulic retention time and hence decrease water treatment capability • high rates will also reduce water depths and shorten the life span of the wetland	• a sediment deposition rate of 0.1 mm/yr (Golder 1998a) means that a 1 m deep wetland with an upland:wetland ratio of 10:1 will have a half life of about 500 years (needs confirmation for different landscapes and does not include any impact of detritus) • rates as low as 0.25 cm/yr reduce seed emergence (Galinto and van der Valk 1986) • sedimentation can impair colonization of the substrate by benthic organisms that are important to wetland functions (e.g., nutrient cycling, decomposition processes) • wetlands generally retain 60% to 90% of inflowing suspended solids (Richardson and Nichols 1985), thereby reducing sediment loads to downstream areas • sediment loads to wetlands should be controlled by minimizing upland sediment yields and designing depositional areas within the landscape (see Appendix C for further information) • texture, slope angle and slope length have a relatively minor impact compared with vegetation cover (Tajek et al. 1985) • good vegetation cover on uplands will greatly reduce sediment inputs to waterbodies • the life span of water treatment wetlands must exceed the period when environmental constituents of concern are released into the wetlands; however, accurate estimates of both lifespan and the duration of water releases are not yet available

Design Factor	Importance/Relevance	Design Considerations
3. Percent Closed Basins	• continuity of wetlands and watercourses provides for integrated landscape drainage, as well as wildlife corridors; drainage networks increase surface runoff and decrease groundwater recharge	• the optimum proportion of closed basins depends on reclamation and landscape objectives; a target of < 20% is suggested at the present time (see Appendix C)
4. Percent Open Water	• open water provides habitat for fish and wildlife species and promotes aeration of the water through wind and wave action	• large open wetlands with little vegetation can be optimal for staging waterfowl and shorebirds • dense overgrown wetlands can be optimal for species such as soras or small passerines • optimum ratio of open water:vegetated area is about 1:1 for breeding waterfowl (Golet 1976) • a 1:1 ratio may be optimum for ammonia degradation (Bishay and Nix 1996) • when a number of wetlands are going to be established in the reclaimed landscape, variation in the amount of open water will provide a diversity of habitats
5. Slopes	• slopes within and immediately surrounding the wetland will affect the nature and sustainability of the wetland	• low slopes around the wetland will decrease water velocities which, in turn, will reduce erosion/sediment input and help maintain hydraulic retention time (i.e., treatment capability) • consistent slopes for a certain distance above and below the shoreline will allow the extent of littoral zones in lakes to be maintained when the water level fluctuates • submerged shoreline slopes of 0.5% are optimum for many aquatic plants and animals (Steiner and Freeman 1989) • slopes within wetlands will depend on the type of wetland being established (e.g., constructed wetlands vs habitat wetlands); to create wetlands similar to natural wetlands, wetland slopes should be gentle (15H:1V or flatter); slopes of wetlands in the region can also be used as guides for contouring (Kentula et al 1992)

Design Factor	Importance/Relevance	Design Considerations
6. Morphology	• the shape of a wetland affects its nature, productivity, etc • features such as islands also provide habitat diversity	• the provision of diverse wetland morphology (e.g., variable depths, undulating shorelines, islands) will provide habitat diversity and enhance the wildlife value of the wetland
7. Sediment and Substrate Permeability	• important for retaining water in wetlands	• if substrates are highly permeable (e.g., tailings sand), water levels will decrease and the wetland may not be sustainable over the long-term; less permeable capping layers (clay substrates) may be needed to reduce substrate permeability and maintain water levels • compaction of soils within the upper one metre, to reduce infiltration, is not recommended since it will restrict plant root growth • wetlands located within discharge areas should not require a liner regardless of substrate permeability provided sufficient surface water or groundwater maintains water levels
8. Sediment and Substrate Type	• substrate texture and topography as well as bedrock geology are important controls on wetland type and distribution (Halsey et al. 1997) • besides water retention, substrate texture has a major effect on vegetation	• areas with and without muskeg placement will increase the variety of habitats and hence biodiversity • organic material can retain metals and enhance nitrogen cycling (Zedler and Langis 1991), hence aiding water treatment • the sources of materials available for placement as substrates should be examined to maximize substrate diversity
9. Turbidity (Water Clarity)	• elevated levels of turbidity can limit the growth of algae, zooplankton, submergent plants and benthic invertebrates; this in turn can indirectly affect fish and wildlife utilization of wetlands.	• sedimentation ponds should be placed upstream of critical habitat wetlands if high sediment yields are predicted for a particular terrain

Table 4.6. Biological key design issues

Design Factor	Importance/Relevance	Design Considerations
1. Toxicity	• process-affected waters from reclamation landforms may be acutely toxic to fish and other aquatic organisms and may cause chronic effects in receiving wetlands	• the standard acute toxicity tests are the 96 h trout toxicity test or the 48 h test for fathead minnows (AEP 1995b); the standard chronic toxicity tests are *Ceriodaphnia* or fathead minnow 7 d tests • treatment wetlands remove acute toxicity (Bishay and Nix 1996) • test ponds and demonstration ponds indicate that chronic aquatic effects dissipate over time; current studies are underway to fully evaluate chronic and sublethal effects • fish habitat may not be possible or fully useable in some treatment wetlands; if the treatment wetland may be suitable in the future for fish habitat, a decision must be made whether to provide fish habitat design features during construction or to incorporate them later
2. Biodiversity	• biodiversity can refer to the diversity of landscapes, communities or species • wetlands often have higher biodiversity than surrounding uplands (Shay 1981) • greater habitat diversity both within and adjacent to wetlands creates increased wildlife value and potential recreational and traditional use value	• Alberta has endorsed the Canadian Biodiversity Strategy • biodiversity can be enhanced by design features (e.g., provision of a variety of types of microhabitats) (Vitt et al. 1996) • wetlands of all sizes are needed to provide a variety of functions and habitats for different species • when a number of wetlands are going to be established in the reclaimed landscape, variation in the amount of open water will provide a diversity of habitats
3. Aquatic Vegetation	• wetlands are among the most productive ecosystems in the world; vegetation is a key component of this productivity • aquatic vegetation provides habitat for many aquatic, semi-aquatic and terrestrial species, including valued wildlife species; in addition, plant surfaces (e.g., stems, leaves) provide a source of attachment for microbes which degrade chemicals	• different wetlands types in Alberta have differing plant productivity; for example, peatlands 557 $g/m^2/yr$, marshes 772 $g/m^2/yr$, swamps 1339 $g/m^2/yr$ (Campbell et al. in prep.) • plant biomass is controlled by depth, slope, exposure, substrate, light, and nitrogen, phosphorus and carbon levels (Wetzel 1983) • a variety of aquatic vegetation species should be established, including those that are important to aboriginal people for their food, medicinal and cultural importance

Design Factor	Importance/Relevance	Design Considerations
4. Riparian Vegetation	• riparian areas may only represent a small percentage of the overall landscape but are critical in terms of biodiversity, wildlife habitat and habitat connectivity • riparian areas stabilize banks, moderate water temperature and provide food and cover for wildlife (Green and Salter 1987)	• plants such as sedges, grasses, bulrushes, and cattails are typical riparian species that should be established • flood tolerant shrub and tree species (e.g., willow) should be established • riparian species of importance to traditional users should be established
5. Upland Vegetation	• upland vegetation provides important cover and habitat; requirements differ by wildlife species • upland vegetation type affects hydrology, erosion and sedimentation	• generally the higher the diversity in plants the higher the diversity in wildlife species • upland vegetation can be planted to provide habitat that is used by wetland species (e.g., some waterfowl)
6. Sediment/Soil	• wetland soils are the foundation for and principal storage of all biotic and abiotic components that exist in wetlands (Kadlec and Knight 1996) • the nature and texture of wetland soils have a dramatic effect on vegetation establishment in created wetlands	• substrate suitability for vegetation establishment in wetlands has been rated (Hammer 1989) • *loamy soils* are especially good since they are soft and friable, allowing easy penetration of rhizomes and roots; *fine textured soils* such as clays may limit rhizome and root penetration ;*pure peaty organic soils* are not recommended by Hammer for wetland development; when flooded they may becomes loose and provide inadequate support for emergent aquatics • according to Hammer's ratings, the peat-mineral mix used as a coversoil in oil sands reclamation will provide a good substrate in terms of nutrients and rooting medium quality • enhancing organic matter in wetland soils will enhance the development of wetland functions (Kentula et al. 1992) • the level of organic matter in natural wetland soils is in the range of 15 to 20%; Stauffer and Brooks (1997) recommend that organic soils or amendments be considered if the existing mineral soils at a created wetland have < 10% organic matter • in the oil sands region a peat-mineral mix is currently used as a coversoil for upland areas; to achieve the minimum 10% organic matter recommended by Stauffer and Brooks, the peat to mineral ratio must be at least 1.5 to 1 (see Appendix C for further information on soil considerations in wetland creation)

Design Factor	Importance/Relevance	Design Considerations
7. Revegetation	• selection of species for revegetation and the methods of revegetation will be a key factor in the success of wetland establishment • a few key factors such as nutrient levels, salinity and depth have a substantial impact on revegetation success • certain species of plants are important for traditional users (e.g., food, medicine, culture) and their establishment would enhance the value of reclaimed wetlands to traditional users	• traditional land users have valuable knowledge that should be accessed to learn how to propagate native plants such as rat root • the fluctuation of water depth must remain relatively small for successful wetland vegetation establishment and development (Hammer 1989); fluctuations in water depth greater than 2 metres pose serious problems for vegetation establishment • donor wetlands (wetlands established as a source of revegetation materials) have the potential to assist revegetation programs; construction of donor wetlands should be considered • species that germinate from seed banks (i.e., muskeg) are often different from those present in donor wetlands (Weinhold and van der Valk 1988) • Brown and Bedford (1997) determined at both a small and a large scale that transplanting organic soil (6 to 7 cm) from a remnant wetland significantly increased the number of wetland species and the amount of cover they provided; they advise against the longterm storage of wetland soils (< 30 days) and that soil placement only be undertaken at the shallower end of the proposed high water level since plant establishment was poor at depths greater than 45 cm (see Appendix C) • transplanting soil from donor sites has too many unknowns to serve as "the sole process for vegetation establishment" (Garbisch 1993) • several studies have shown that natural recolonization is a major factor in vegetation establishment in created wetlands and that species that are transplanted do not always establish or maintain themselves; however, this may relate to the appropriateness of the species selected (see Appendix D for further information) • Reinartz and Warne (1993) showed that biodiversity increased if the wetland was seeded with native species (only a 2 year study) • planting increased diversity and attracted animals that served as natural vectors for seed dispersal from other wetlands (Klein 1992)

Design Factor	Importance/Relevance	Design Considerations
8. Connectivity	• the degree of connectivity between wetlands affects wetland development and habitat functions and values	• connecting wetlands by using watercourse design will increase habitat value and wildlife diversity • waterfowl value of a wetland is enhanced if within 3.2 km of other wetlands (K. Lumbis, pers. comm.) or within 1.6 km of permanent waterbodies (Golet 1976)
9. Mammals	• wetlands are valuable habitat for a variety of mammals from water shrews to beavers and moose; also, they are integral to wetland ecology (i.e., structure and functions) and also add to overall biodiversity	• streams developed for beaver habitat should be designed with gradients <15% and adjacent slopes <45% to promote dam construction and establishment of pools (J. Martin, pers comm.) • relatively stable water levels are required to maintain muskrat and beaver populations over the short-term • wetland habitat features that support moose should be considered due to the importance of moose to aboriginal peoples (e.g., slope, depth, vegetation for cover and food) • Appendix E provides further information on design considerations for wildlife habitat
10. Waterfowl (and other birds)	• wetlands provide valuable habitat for a variety of waterfowl and shorebird species	• aquatic habitat requirements in the Central Mixedwood Natural Subregion are poorly known for many species (see Appendix E) • for isolated wetlands, a minimum size might be 5 ha, for connected wetlands or wetlands within a complex, the minimum size might be 0.2 ha (Lokemoen 1973) • waterfowl value of a wetland is enhanced if within 3.2 km of other wetlands (K. Lumbis, pers. comm.) or within 1.6 km of permanent waterbodies (Golet 1976) • optimum water depths for foraging shorebirds range from 0 cm (mudflat) to 18 cm • reclaimed wetlands have the potential to provide habitat required in the annual life cycle (e.g., spring migration, pairing, nesting, brooding, rearing, moulting, fall staging); in addition, artificial nesting and habitat structures can be provided (see Appendix E for design considerations for the different stages and the ability of wetland types on the reclaimed landscape to provide the different types of habitat required by waterfowl)

Design Factor	Importance/Relevance	Design Considerations
11. Fish	• the potential exists to create habitats in littoral zones of end pit lakes, water-courses and marshes which provide good spawning, rearing, feeding and overwintering areas for sport and forage fish (L. Rhude, pers comm.)	• forage fish such as brook stickleback and Cyprinids (minnows) will likely colonize many wetlands • small permanent wetlands can provide habitat for a variety of fish; ephemeral streams can provide seasonal and spawning habitat for some species • there is potential to establish sport fish habitat; however, fish habitat should not be developed in areas that may exhibit potential toxicity; at a minimum, fish habitat will be able to be created in the outlets from lakes • lake littoral zones, flood control wetlands and watercourses can provide fish habitat; in addition. artificial structures can be provided (see Appendix E for further details)
12. Amphibians	• some species may be key indicators of ecological changes	• wetlands designed to provide habitat suitable for waterfowl and wildlife should provide wetland systems suitable for amphibians (see Appendix E for further information)

Table 4.7. Chemical key design issues

Design Factor	Importance/Relevance	Design Considerations
1. Salinity	• salinity is a major issue that will shape the character of reclaimed wetlands (see Appendix F) • salts can cause toxicity – impact varies by species of plants and animals; salts affect biodiversity and suitability of habitat for plants and animals • salinity limits bryophyte growth and hence peatlands (Vitt et al. 1993) • salinity can limit algal production (Dillon and Rigler 1974; cited in Nix et al. 1991) • salinity can impact animals; for example, affecting growth rates of ducklings (Swanson et al. 1984) • salinity may affect treatment efficiency for removal of environmental constituents of concern (i.e., lower rates of biodegradation of hydrocarbons, ammonia or naphthenic acids due to less plant surfaces for attachment of biofilms) • salinity may affect nutrient cycles in wetlands	• levels of salinity comparable to natural background concentrations would be best; however, some elevation in salinity levels may be acceptable as long as the wetland meets ecological goals (e.g., specific level of biodiversity) or treatment goals (e.g., specific levels of degradation for constituents of concern) • some saline wetlands may be acceptable in the reclaimed landscape providing they are a biologically viable and sustainable; they may be "intermediate" wetlands in the sense that salinity should dissipate over time • salinity is not effectively reduced by wetlands; in fact, wetlands can concentrate salts if there is inadequate flushing • salinity may increase over time in any closed system; therefore, increased flushing and connectivity will reduce salinity • most freshwater invertebrates can tolerate periods of exposure at levels up to 6,000 mg/L (Wetzel 1975); however, some toxicity may occur at levels as low as 1,000 mg/L (Hart et al. 1990) • adult fish are quite tolerant of high salinity and impacts are unlikely below 8,000 mg/L (Hart et al. 1990) • the design of water treatment wetlands will have to consider the possible influence of salinity on treatment capability
2. Ammonia	• ammonia is a typical contaminant in crude oil processing facilities and amine scrubbers • partially, but not solely, responsible for acute toxicity to fish when > 1 mg/L (Nix et al. 1995) • typically >5 mg/L in process-affected water • provides a source of N to wetlands which may enhance plant and animal growth	• ammonia can be degraded in wetlands by aerobic and anaerobic microbes with a retention time of about 30 d (Bishay and Nix 1996), • optimizing natural aeration processes in the wetlands (i.e., areas of open water) will promote removal of ammonia • experimental water treatment wetlands have removed >75% of the ammonia entering the wetland (Bishay 1998)

Design Factor	Importance/Relevance	Design Considerations
3. Naphthenic Acids	• naphthenic acids occur naturally in oil sands bitumen and have properties associated with surfactants (CEATAG 1998) • naphthenic acids contribute to both acute and chronic fish toxicity • there is uncertainty regarding chronic toxicity effects on wildlife	• naphthenic acids require long retention times for their removal (i.e., about one year; Bishay and Nix 1996) • quantification by chemical analysis is difficult and may not be accurate; studies are currently underway to further advance analytical methods for naphthenic acids • criteria for acute and chronic toxicity do not currently exist; whole effluent toxicity approaches can be used to evaluate treatment wetlands or water releases from treatment wetlands (OSWRTWG 1996); discussion paper is available on naphthenic acids (CEATAG 1998) • Syncrude and Suncor have conducted a number of field and laboratory studies on the toxicity of naphthenic acids; as well as investigations on analytical methods
4. Dissolved Oxygen (DO)	• dissolved oxygen is required for respiration by plants and animals and many (aerobic) microbes • valued aquatic organisms (e.g., sport fish) require high levels of oxygen • DO inputs via wind and waves may be crucial for treatment of high loading of organic compounds or materials	• open water areas promote oxygenation of the water column; this ensures water treatment success and a healthy biological system • provision of a variety of aerobic/anaerobic zones in the sediment or biofilm will aid the capability of water treatment wetlands • plants can transfer oxygen to the sediment (Mendelssohn et al. 1995) but studies have indicated that low oxygen levels may still limit microbes in wetlands with inputs of process-affected water, particularly in the winter (Nix et al. 1995) • design features can enhance wind mixing (e.g., increased fetch, orientation and exposure to prevailing winds)
5. Metals	• metals can exhibit toxicity to aquatic organisms and some can bioaccumulate in vegetation or be biomagnified through the food chain; it may be years before this effect is evident • metals tend to be retained in wetlands sediments and vegetation (SETAC 1998) • natural processes such as methylation can make metals bioavailable	• no substantial uptake into plants and animals has been observed based on preliminary on-site research (Nix et al. 1994; Bishay and Nix 1996), but some metals may exceed risk-based concentrations (Golder 1998b) • at high concentrations metals are not removed well in wetlands

Table 4.8. Nutrient key design issues

Design Factor	Importance/Relevance	Design Considerations
1. Phosphorus (P)	• phosphorus is a basic nutrient for all cellular life and a fundamental requirement for biological processes • often a limiting nutrient in freshwater systems (Hutchinson 1957) and likely in many oil sands wetlands system (Nix and Power 1989) • low levels limit waterfowl production (Concord Scientific 1989)	• wetlands tend to remove phosphorus (Kadlec and Knight 1996) • adding phosphorus would enhance biodegradation processes (Bishay and Nix 1996); however, too much decreases biodiversity and treatment effectiveness • phosphorus levels increase with catchment area (Prepas and Trew 1983)
2. Nitrogen (N)	• nitrogen is a basic cellular nutrient required by all organisms • generally there are adequate levels in freshwater systems	• nitrogen can be incorporated into a wetlands from the air through natural microbial processes
3. Carbon (C)	• carbon is the basic molecular building block for all plants and animals • peatlands store vast quantities of carbon and help balance the global carbon cycle (Gorham 1991)	• a ratio of C:N:P of about 100:10:1 is optimal for most organisms • emergent macrophytes (e.g., bulrushes) have higher levels of structural carbon which is less utilizable by organisms; therefore, these plants have lower food value • submergent and floating macrophytes (e.g., duck weed) have more nutrients and more utilizable carbon; therefore greater food value (SETAC 1998)

Table 4.9. Traditional use key design issues

Design Factor	Importance/Relevance	Design Considerations
1. Spiritual and Cultural Activities	• certain wetland areas are of spiritual and cultural importance to aboriginal communities	• aboriginal communities should be consulted to determine design factors that are important for cultural and heritage purposes
2. Traditional Plants	• certain plants are important to aboriginal communities as food and medicine, as well as for spiritual and cultural purposes	• further knowledge about important plant species is needed; traditional users should be consulted for their knowledge of wetland plants • Appendix I provides a list of traditional plant species common to the oil sands region
3. Revegetation	• revegetation and subsequent ecosystem development will determine the diversity and density of wildlife species utilizing the wetland • revegetation and subsequent ecosystem development will determine the degree to which plants used by aboriginal peoples are established in reclaimed wetlands	• vegetation in reclaimed marsh communities should be comparable to natural marshes in the area • revegetation methods should endeavor to re-establish plant species used by aboriginal communities; revegetation methods for certain traditional plants are not well known and will need to be developed • a seed bank should be established for native species that can be reseeded; the development of local harvesting or greenhouse industry should be promoted to supply native plant species • donor wetlands/muskeg may enhance revegetation success for large areas or for wetlands which may need to begin to function rapidly after their establishment (e.g., water treatment) • natural colonization may succeed over time, but rapid colonization by selected species (e.g., cattails) may impede biodiversity • transplanting can be costly and, in some cases, unnecessary (Kentula et al. 1992) • Appendix D provides more details on vegetation considerations in wetlands creation

Design Factor	Importance/Relevance	Design Considerations
4. Wildlife	• wetlands provide valuable habitat for a wide variety of aquatic and terrestrial species used by aboriginal peoples	• waterfowl should be a key indicator of wildlife habitat (i.e., good waterfowl habitat will be good wildlife habitat) • other species (e.g., muskrat) should be selected in consultation with aboriginal representatives, depending on the wildlife that a particular wetland is intended to provide • a variety of wetlands types are utilized by waterfowl • a diversity in wetlands types and sizes across the landscape is optimal • deciduous shrub and tree species should be planted if beaver habitat is desired (e.g., aspen, willow); however, designing for beaver will have a significant effect on the development and maintenance of habitat for other species since beaver exert a significant influence on the landscape
5. Fisheries	• wetlands in the reclaimed landscape can provide habitat for larger fish species (e.g., spawning habitat for northern pike), as well as habitat for forage fish species • lakes, including their littoral zones, have the potential to provide fish habitat	• the overall design of end pit lakes is not addressed in this guideline; end pit lake design will consider the provision of fish habitat, including habitat provided by littoral zones • for the purpose of this guideline, the objective is to design for fish habitat only in outlet channels from end pit lakes and larger streams with a catchment area > 20 km^2 (Golder 1998a); however, permanent wetlands can provide spawning and rearing habitat for species such as northern pike (Scott and Crossman 1973), as well as habitat for forage fish species

4.3.4 Hydrology and Water Quality

The planning and design of wetlands requires predictions of the hydrology and water quality of wetlands to be established on the reclaimed landscape. Both of these factors are key determinants in wetland development and performance. Figure 4.4 provides a framework for evaluating probable hydrology and water quality conditions and using the information for wetland planning and design. Appendices C and D provide further information with respect to hydrology at the landscape and wetland level.

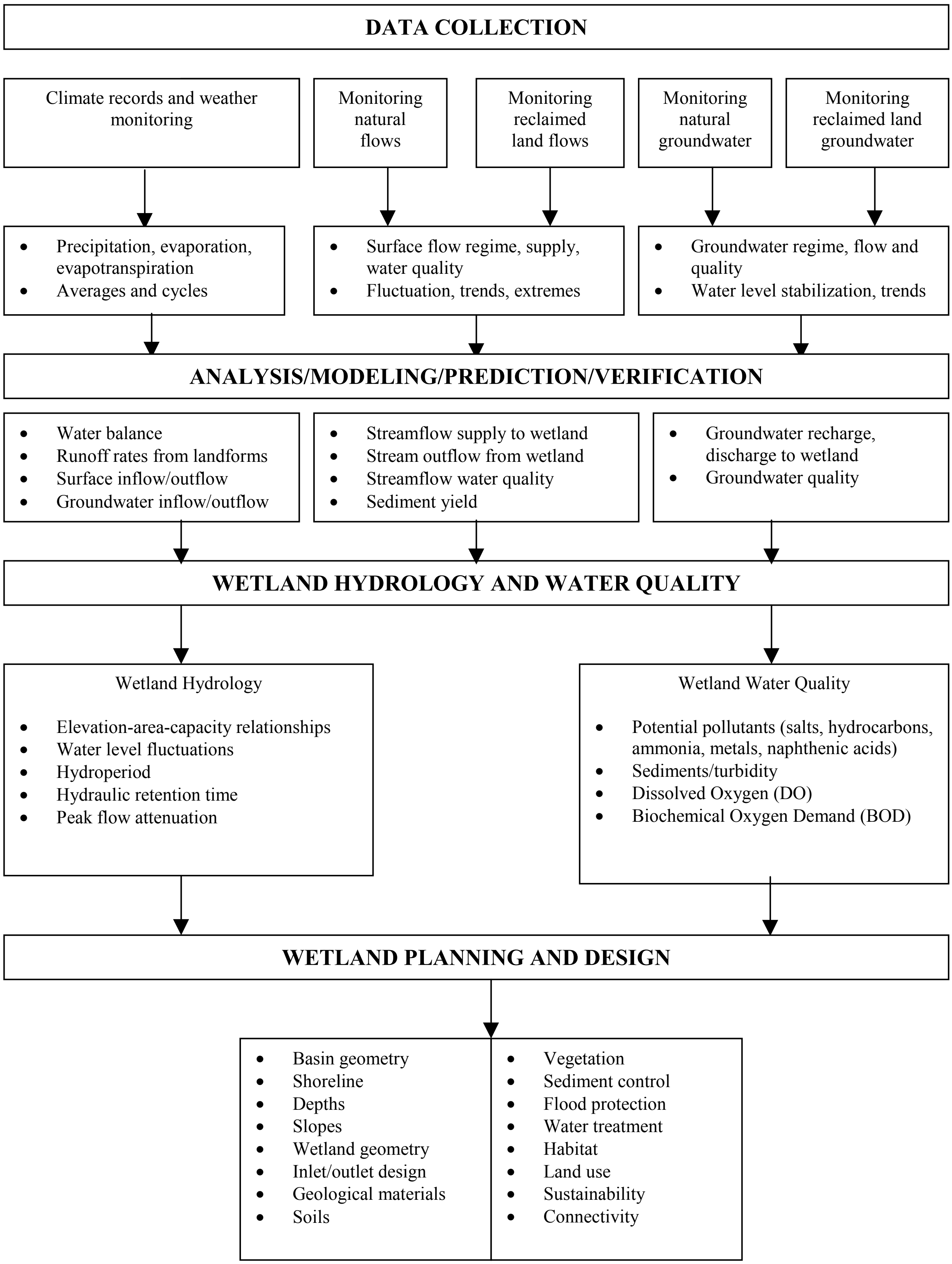
Hydrology. Mitsch and Gosselink (1993) state that *"Hydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetlands and wetland processes."* Moshiri (1993) adds that *"Clearly, hydrology is the driving factor regulating the presence, characteristics, biology and productivity of wetlands."*

Hydrology creates the physical-chemical conditions in wetlands which in turn determine the biological community that will be present. Hydrological pathways such as precipitation, surface flow, and groundwater flow move energy and matter into and out of the wetland. Hydrologic inputs and outputs determine water depth, the seasonal water level pattern (hydroperiod) and the extent and duration of flooding. These in turn influence the biochemistry of wetland soils which exerts a major influence on the biota that establish in the wetland. As a result, hydrologic conditions affect the biological community from the level of microbes to invertebrates to vegetation to waterfowl. Given the major role of hydrology in wetland systems, small changes in hydrology can result in significant changes to the ecology of wetlands (e.g., species composition, species diversity, ecosystem processes, ecosystem productivity). On the other hand, stable hydrological systems promote stable ecosystem structure and function over time.

Wetland creation requires a thorough understanding of the water budget and hydroperiod. Eastlick (1993) notes that the most useful data will be from real time measurements on the actual watershed in question. Alternatively, professional hydrologists can provide: 1) data estimates using climate statistics and computer simulations, or 2) information scaled from records for an analogous watershed in the region.

Water quality. Water quality in wetlands is of particular importance in the oil sands region due to the potential releases of process-affected water from the reclaimed landscape over long periods of time. Wetland planning needs to consider the ability of wetlands to achieve water quality improvements, in particular for water treatment wetlands. The types of potential contaminants (e.g., hydrocarbons, ammonia, metals, naphthenic acids and salts) and their transport and fate processes will be factors in wetland design. Contaminants released to wetlands are attenuated by a wide variety of physical, chemical and biological processes, including sedimentation, volatilization, adsorption, chemical reactions and microbial and plant metabolism. Projections of expected water quality will be needed.

Figure 4.3. Outline of procedures and components in determining probable hydrology and water quality in reclaimed wetlands (adapted from Nelson et al. 1982)



4.4 Establishment of Specific Wetlands Types

4.4.1 Overview and Wetland Management Flow Chart

A number of different wetland types will be established on the reclaimed landscape. As previously discussed, the five types are:

1. altered wetlands;
2. opportunistic wetlands;
3. constructed wetlands (three types: flood control, water treatment, habitat);
4. vegetated watercourses;
5. littoral zones.

The development of wetlands does not imply a strictly engineered approach; for example, weirs and pipes would only be used over short periods if at all. Rather, mine closure planners and engineers should shape the landscape to create wetlands with characteristics (e.g., slopes, total area, retention times) that will support the intended functions. The exception might be water treatment wetlands which may require temporary engineered structures such as weirs to control water flow to maintain a retention time required for treatment of a specific compound. However, even these treatment wetlands will likely evolve into more "natural" wetlands as the need for water treatment diminishes over time. This will allow any structures requiring maintenance to be dismantled before certification.

Figure 4.5 provides a wetland management flow chart as an overview and guide to the establishment of the five wetland types. To facilitate wetland design, the following information is presented in sequence for each type of wetland:

1. general description to provide an overview, rationale and comments;
2. development flow chart to outline the design and implementation process;
3. key issues checklist and selected design recommendations (to be used in conjunction with tables on landscape considerations (Table 4.2) and key design issues (Tables 4.4 to 4.9);
4. development approach sheet to provide a form that can be used to design the wetland.

Figure 4.4 Wetland management flow chart

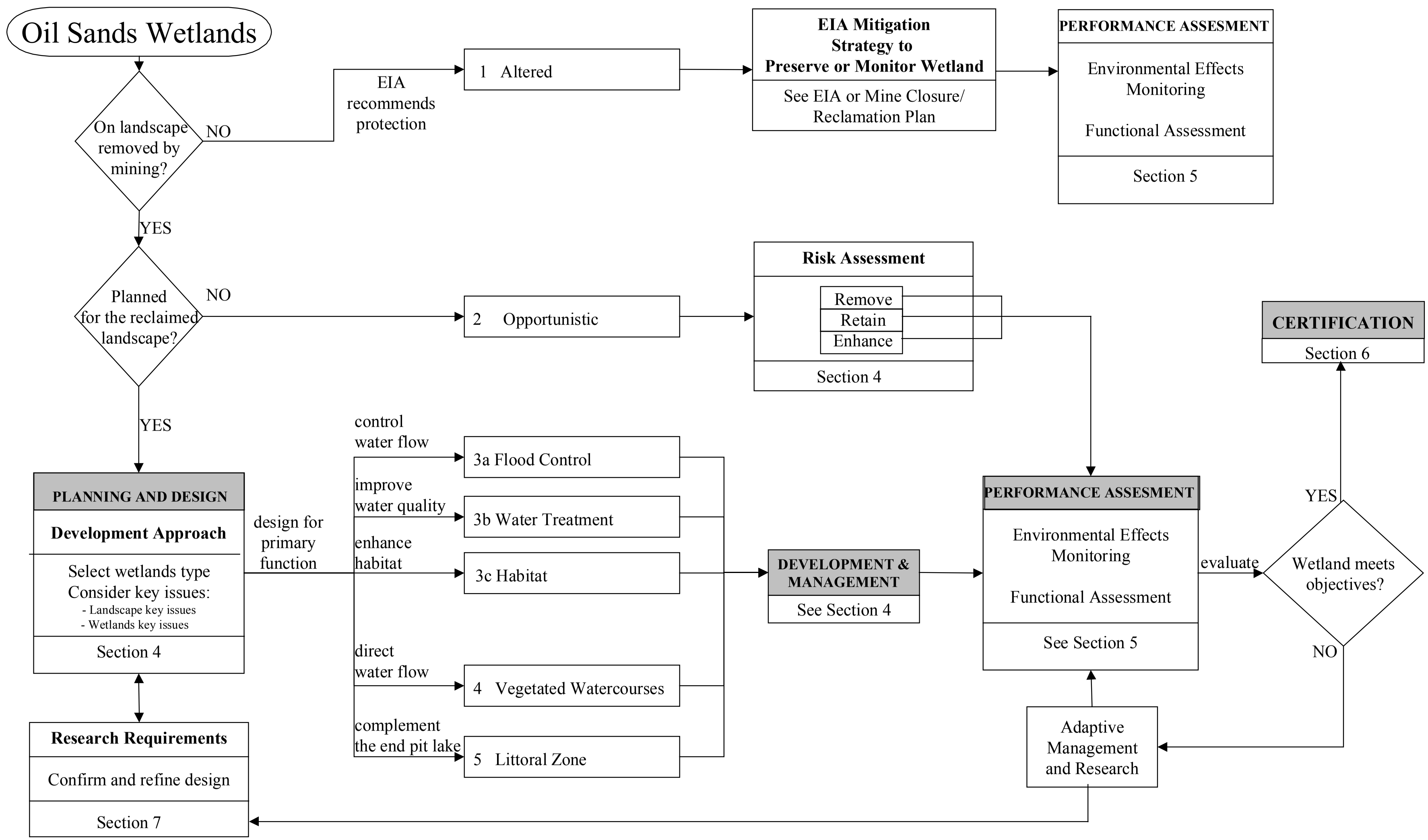


Figure 4.5 illustrates how the four principal stages of wetland development are applied to each wetland type. As discussed in Section 1.3 the principal stages are: 1) planning and design, 2) development and management, 3) performance assessment, and 4) reclamation certification.

Altered wetlands will only require performance assessment to determine if mitigation strategies to preserve the wetland have been successful. Altered wetlands will not require reclamation certification. Opportunistic wetlands, which arise inadvertently on the reclaimed landscape, will require a risk assessment process to assess their suitability on the landscape. The risk assessment will determine if a particular opportunistic wetland should be removed, retained or enhanced. If it is retained or enhanced, performance assessment and certification will follow. Constructed wetlands, vegetated watercourses and littoral zones will encompass all four principal stages.

The development approach used in this guideline establishes the principal function required for each wetland type as the basic guide for wetland development. However, it does not provide a detailed construction design since:

1. the guideline is a generic approach (i.e., the focus is on the overall design process and the key issues that need to be addressed versus prescriptive details)

2. the hydrological, physical and chemical characteristics of reclamation landforms (including the nature of their release waters) need to be known in order to plan and design wetlands; however; these landforms are not fully understood and some (e.g., CT deposits) have, for the most part, not been built; in addition, the planned features of reclaimed landforms may change over time

3. the hydrological, physical, chemical and biological characteristics of reclaimed wetlands are not fully understood at present

4. decisions on end land use may affect design requirements (e.g., some wetlands may be needed for harvesting of some traditional plants).

The separation of multiple wetland functions into single categories is not a simple task and is overly simplistic since functions are often interrelated, the operation of one depending on the operation of another (Westworth 1993). For example, the success of water treatment and habitat wetlands will depend very much on the capability of flood control wetlands to moderate potential large variations in water flow. Further, distinctions between wetland types may also relate to temporal considerations (see Section 4.3.2) For example, a water treatment wetland should evolve into a habitat wetland as the volume of process-affected water entering the wetland decreases over time.

The development approach sheet for each wetland type establishes basic design features needed for the wetland to perform its primary function (e.g., flood control, water treatment, habitat). It identifies key issues that need to be considered. Design recommendations for these issues are provided in the key issues checklist for each wetland type, as well as the key issues tables in Section 4 (Tables 4.4 to 4.9 provide general design considerations for hydrology, physical attributes, biology, chemistry, nutrients and traditional use. Table 4.2 provides general landscape considerations in wetland planning).

Figure 4.5 shows that research is needed to provide improved information for wetland planning and design. This research may modify the design recommendations in this guideline or identify further design features that may be necessary. Further, it is likely that even after construction an adaptive management and research component will be required to enhance the performance of these wetlands or to adapt to changes in water quality or other variables.

4.4.2 Altered Wetlands

4.4.2.1 General Description

Overview

Altered wetlands are onsite or offsite wetlands that are not directly removed by mining but are potentially affected through drainage changes, water table drawdown, dewatering, etc. They may have significant values or functions that warrant conservation of the wetland as determined through the environmental impact assessment (EIA) process.

These wetlands include two main types: marshes and peatlands. Most are peatlands.

1. Marshes: natural wetlands with transitional zones from open water to riparian and perhaps supporting fish and wildlife habitat (e.g., Shipyard Lake) or having heritage value (e.g., Isadore's or Cree Burn lake).
2. Peatlands: transition zones between upland and aquatic ecosystems, storing and attenuating waters between these two zones, and affecting waters passing through them (National Wetlands Working Group 1998). Regionally, poor fens have a mean water table located 16±10 cm below the peat surface, while moderate-rich fens have a mean water table of 14±7 cm below the peat surface (Nicholson et al. 1996).

Since these wetlands will be evaluated within the EIA process, the guideline does not provide a key issues checklist or design recommendations. Any mitigation strategies required will be developed through the EIA process and subsequent regulatory approvals. If mitigation (i.e., conservation) is warranted, the intent is to monitor these wetlands to determine the nature of ecological changes, gain understanding of effects and undertake further action if needed.

Rationale:

1. Dewatering of peatlands will initiate changes in their evolution and ecology. Complete dewatering would convert them to upland forests. This might be positive to the forest industry but would impact on wetlands functions such as downstream water quality (e.g., pH) (Halsey et al. 1998) and quantity (e.g., flood control) (see Appendix G). Dewatering would also affect traditional uses.
2. Marshes may require protection due to their value as fish habitat or wildlife habitat (e.g., important wildlife travel corridors and habitat areas along river valleys).

Comments:

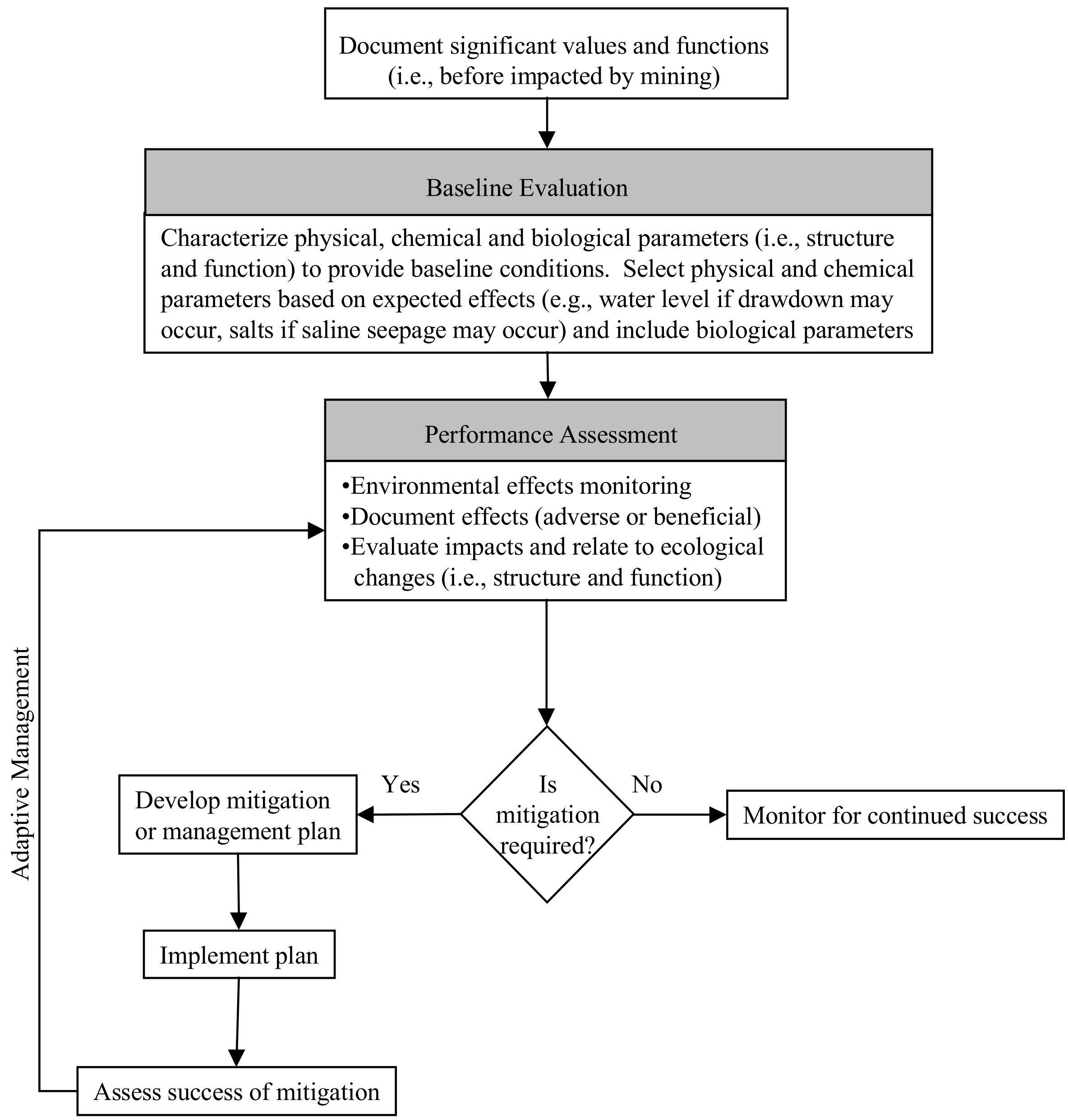
Mitigation of dewatering impacts is not discussed in this guideline since this issue is addressed by EIA reports and project approvals based on input from regulators and stakeholders, including aboriginal communities. EIA's and mine closure plans have provided considerable detail on the need to mitigate any adverse impacts of mining on important marsh systems; however, potential impacts of dewatering on adjacent peatlands systems may need further study.

Impacts of water table drawdown will be a function of its magnitude and will result in a host of physical, biological, and chemical changes. A drop in water table of 70 cm will result in severe impacts (Zoltai et al. 1999). Water table declines in the range of two standard deviations (20 cm for poor fens and 14 cm for moderate-rich fens) will be moderate and probably lead to changes in peatland function (Gignac et al. 1991a,b). Water table declines below this level will allow wetland functions to continue, though species may change. Dewatering and subsequent oxidation of peatlands may also result in a release of metals (Folsom et al. 1988). There would also be potential release of greenhouse gases. Maintaining water tables may be difficult and this issue has been discussed in other regions (e.g., Okruszko 1995; Schothorst 1977).

4.4.2.2 Altered Wetlands Management Flow Chart

Definition: Onsite or offsite wetlands that may be potentially impacted by mining activities and have significant values or functions that warrant conservation of the wetland as determined by an EIA.

Objective: If mitigation (i.e., conservation) is warranted, the intent is to monitor these wetlands to determine the nature of ecological changes, gain an understanding of the processes involved, and take appropriate remedial action.



4.4.3 Opportunistic Wetlands

4.4.3.1 General Description

Overview

Oil sands mine reclamation has already produced several "opportunistic" wetlands. These wetlands are not formally planned but arise inadvertently from depressions that form in the reclaimed landscape (i.e., due to differential settling of landforms), a rise in the water table or impeded drainage (surface or groundwater). Therefore, their characteristics will vary widely in terms of their physical nature (shallow to deep); water quality (saline to freshwater); and ecology (high productivity and diversity to low productivity and diversity). They might occur on the plateau, slope, or toe of reclamation landforms.

Opportunistic wetlands can provide valued functions on the reclaimed landscape (i.e., flood control, water treatment and habitat). They may be permanent, semi-permanent or temporary, all of which have potential habitat value.

At Suncor several opportunistic wetlands presently exist: the Natural Wetlands and the High Sulphate Wetlands. Each has been the focus of considerable study to model the eventual characteristics of constructed or created wetlands. Each has developed through a unique set of circumstances resulting in a system that has characteristics that are different from those existing prior to the mine development.

Rationale:

Opportunistic wetlands can provide functions related to flood control, water treatment and habitat. The inadvertent creation of these wetlands presents mine closure and reclamation planners with three choices:

1. *Remove*: if they present a danger or create a potential adverse impact on the landscape; for example, located on benches or slopes of waste dumps where they might increase erosion or gullying processes. Alternatively, they might be removed if the catchment area was too small to sustain them in the long-term.
2. *Retain*: if there is no particular risk. Also, natural processes of conversion to dry lands might be considered acceptable if their total size was small in comparison with the reclaimed area.
3. *Enhance*: if there is opportunity to add significant functional value either locally (e.g., fish habitat, water treatment) or for the entire landscape (e.g., terrestrial wildlife, recreation, connectivity, wildlife travel corridor). Opportunistic wetlands that will be enhanced should be located at lower elevations so that the potential drainage basin is large enough to sustain them indefinitely.

The overall objective is to integrate opportunistic wetlands that are likely to be sustainable into the reclaimed landscape. They can initiate wetland establishment on the landscape since they will arise early in the post-mining landscape.

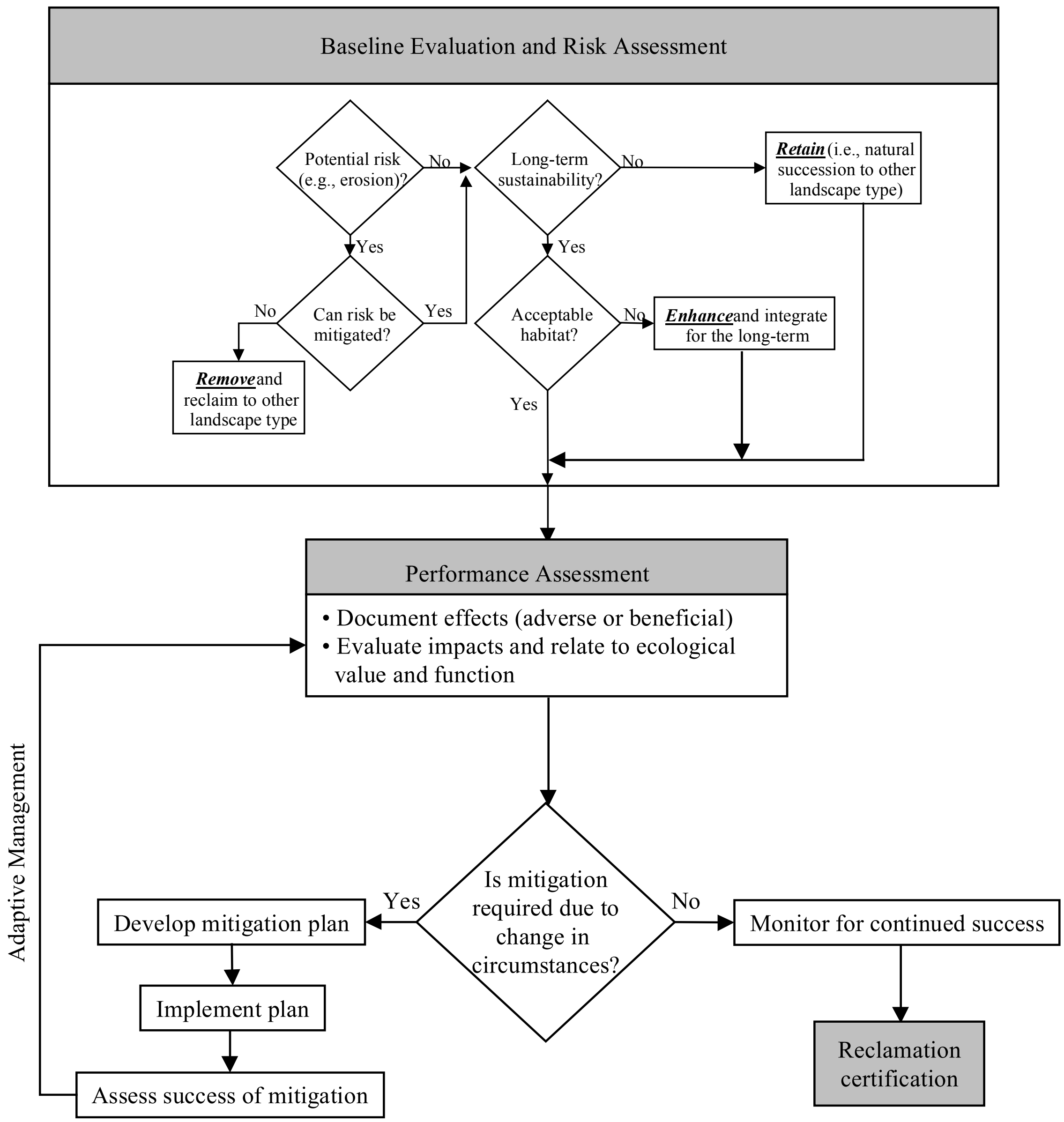
Comments:

Wildlife utilization of opportunistic wetlands will be highly variable and largely dependent on factors including basin morphometry, water quality, hydrology, substrate type and vegetation communities. Where possible, their retention is recommended to enhance habitat diversity and distribution on the reclaimed landscape.

4.4.3.2 Opportunistic Wetlands Management Flow Chart

Definition: Wetlands that are not formally planned but arise inadvertently from depressions that form in the reclaimed landscape (e.g., due to differential settling of landforms), an increase in water tables or impeded drainage (surface or groundwater).

Objective: To integrate opportunistic wetlands that are likely to be sustainable to aid in "jump starting" reclamation landscape since these wetlands form early in the post-mining landscape.



4.4.3.3 Key Issues Checklist for Opportunistic Wetlands

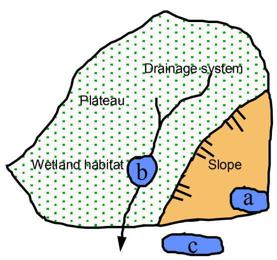
Issue	Selected Design Recommendations
1. Remove	• infill – using available material and as per terrestrial reclamation • drain – connect to existing drainage
2. Retain	• no action needed – go to performance assessment (see Section 4.4.3.2 which presents the Opportunistic Wetland Flow Chart)
3. Enhance	• berm one or more sides to increase depth and/or total area and thereby retention time to improve water quality • connect to existing wetlands, watercourses, streams or lakes using vegetative watercourses; this will improve habitat values such as waterfowl use – especially if the opportunistic wetland is within 3.2 km of another wetland • add overburden and/or muskeg around the shoreline to increase shoreline length and create irregular configuration (i.e., to maximize edge and habitat diversity) • add overburden within wetlands to create islands (i.e., wildlife refuge) • if saline, revegetate with saline tolerant plants (see Appendix F) or with material (e.g., sediment, seeds) from a suitable donor wetland; Appendix F is for information only, species used for wetland reclamation should be native to the oil sands region (i.e., the Central Mixed Wood Region of the Boreal Forest)

4.4.3.4 Development Approach Sheet for Opportunistic Wetlands

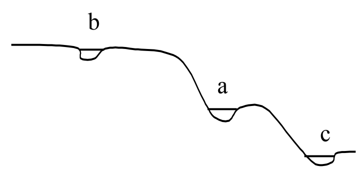
PRIMARY FUNCTION: *Potential for flood control, water treatment or habitat functions determined during the risk assessment process (see Section 4.4.3.2)*

Site Identification

Schematic - Aerial View



Schematic – Profile



Site-Specific Sketch

Key Issues (see Section 4.4.3.3)	Relevant Data/Comments	Development Approach for Site-Specific Design
a) Remove		•
b) Retain		•
c) Enhance		•

4.4.4 Flood Control Wetlands

4.4.4.1 General Description

Overview

These wetlands provide hydrological functions related to flood control and peak flow attenuation. They prevent downstream flooding and/or flush saline waters. Flood control wetlands would consist of wide shallow areas to provide a large water retention capability. The centre of a flood control wetland should have a deeper channel to provide drainage during periods of low flows.

Rationale:

Flood control wetlands are needed in the reclaimed landscape to decrease peak flows. This decrease will also result in reduced sediment loading to receiving streams or other wetlands. The ratio of watershed to wetlands area should be no higher than 20:1 (Golder 1998a). The basis for this ratio is that a catchment area higher than 20:1 can cause high through-flow that may increase the risk of channelization through the wetland. This would reduce the effectiveness of the wetland both in terms of flood control and water quality treatment. Further, the wetland could eventually deteriorate as sediments build up in the areas adjacent to the channel.

These wetlands will allow a more constant, moderated flow of water into downstream treatment and ecological wetlands. For downstream treatment wetlands, a moderated water flow is desirable to allow for the long retention times needed for the bacterial degradation of constituents in process-affected water such as ammonia and naphthenic acids. For downstream habitat wetlands, a moderated water flow would provide more constant water levels and, therefore, more sustainable plant and animal communities.

For those reclaimed landforms which release saline waters, downstream wetlands would serve a dual function: 1) in times of flood, saline water would be diluted and dispersed throughout the flood plain/wetlands (diluted saline water would have less impact on plants and animals); and 2) in times of low flow, more concentrated saline waters would be restricted to the main channel (thereby with less impact of salts on soils in the floodplain).

These wetlands have the potential to provide critical spring migration habitat for waterfowl and shorebirds, which is contingent on the quality of water. Shallow water depths in the floodplain are requisite to optimizing utilization and a gradual drawdown will prolong the availability of invertebrates to foraging birds. Migratory shorebirds and waterfowl use habitats of variable depth, vegetation height and density which harbour rich invertebrate food resources.

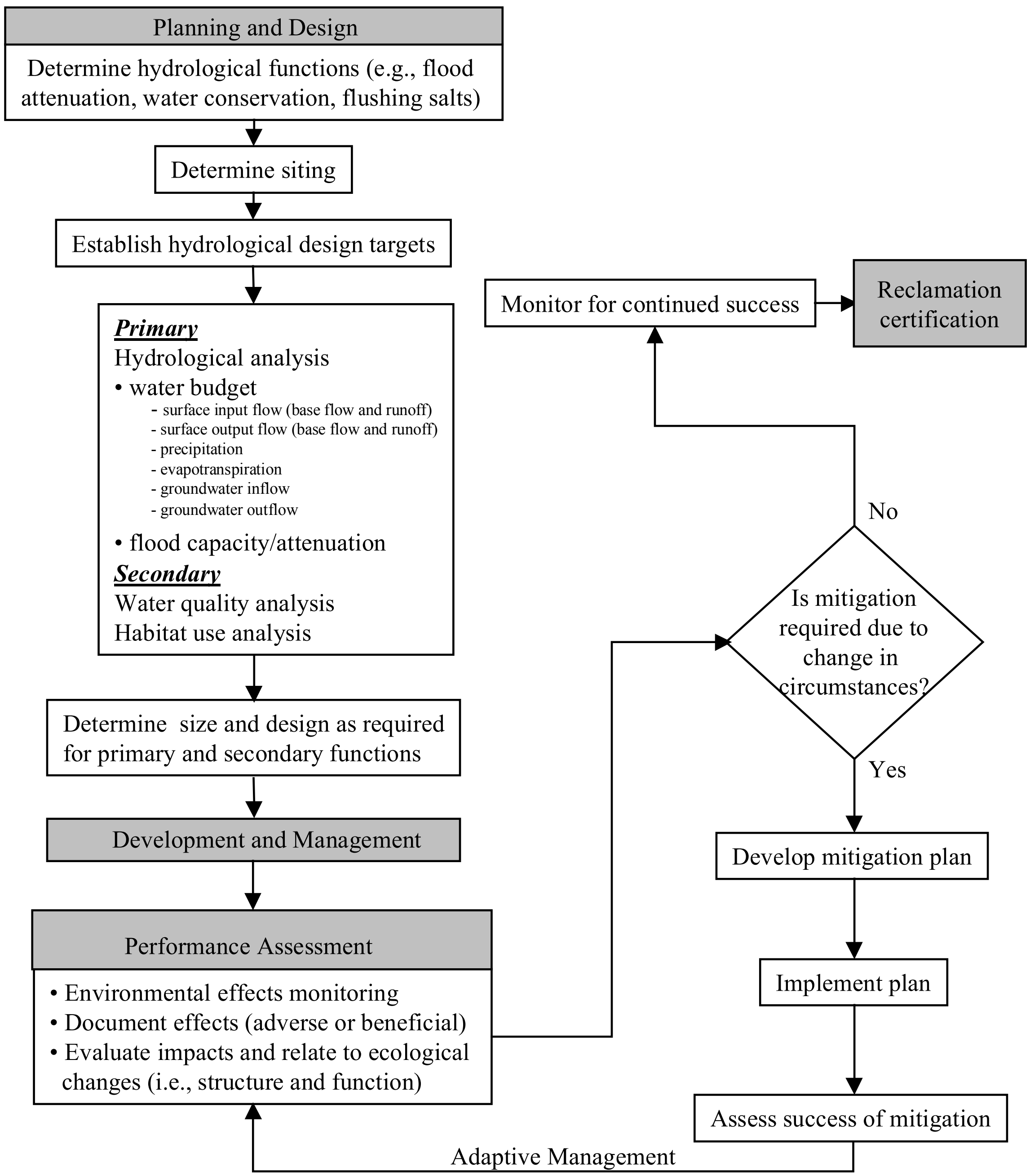
Comments:

These wetlands will provide adequate water depths and acceptable water level fluctuations if design guidelines are incorporated, including proper design of outlet channels. The broad floodplain will accommodate high flows with minimal water level fluctuations during consolidation of the reclaimed mine area. The relatively narrow channel will maintain water levels or minimize outflows during periods of drought – its design will be crucial to adjusting the hydraulic retention time to correspond to peak waterfowl and shorebird migration periods. The small outlet channel should be engineered with coarse alluvial material for sustainability of the channel shape for at least 50 m downstream, at which point standard watercourse design guidelines can be used (Golder 1998a).

4.4.4.2 Flood Control Wetlands Management Flow Chart

Definition: A constructed wetland that is planned and designed to provide hydrological functions (flood control, peak flow attenuation, prevention of downstream flooding, flushing of saline water).

Objective: To provide functioning wetlands with a primary role of flood control.



4.4.4.3 Key Issues Checklist for Flood Control Wetlands

ISSUE	SELECTED DESIGN RECOMMENDATIONS
1. Watershed to Wetland Ratio	• maximum recommended ratio is 20:1 (Golder 1998a); that is, the area of wetlands should be at least 5% of the entire catchment area; the basis for this ratio is that a catchment area higher than 20:1 can cause high through-flow that may increase the risk of channelization through the wetland; this would reduce the effectiveness of the wetland both in terms of flood control and water quality treatment; also the wetland could eventually deteriorate as sediments build up in the areas adjacent to the channel.
2. Water Depth in the Floodplain	• in the floodplain: variable depths to a maximum of about 30 cm would benefit waterfowl/shorebirds in spring migration (K. Lumbis, pers. com)
3. Soil/Sediment Permeability	• in the floodplain: highly permeable sediments will drain the wetlands more quickly and hence have less impact on terrestrial plants in the floodplain
4. Water Velocity	• in the floodplain: water velocity should be sufficient to move water and prevent permanent flooding, but slow enough to prevent erosion
5. Floodplain Topography	• in the floodplain: a range of wetlands elevations will provide productive migration habitat for birds (e.g., sparsely vegetated mudflats, vegetated open shallow ponds) and a diverse habitat for aquatic plants and animals
6. Area	• in the floodplain: the design recurrence interval should be equal to, or greater than 2,000 years in order to provide a sustainable closure plan (Golder 1998a); extensive shallow flooding (30 cm or less) over relatively large areas (10 x channel width) should be promoted
7. Peak Water Flow	• on the CT landform, peak flows may diminish over time; therefore, consider designing for the maximum area of wetlands (i.e., 20% of total catchment area) and/or make the depth of each valley about 4 m to ensure that water is retained (this is also a depth which will inhibit excessive flooding by beavers) • if possible, flooding should coincide with peak waterfowl and shorebird migration from late April to May (K. Lumbis, pers. comm.)
8. Central Channel	• can maintain a channel with water during period of low flow • may not be needed; may cause too rapid drawdown (less flood control) • alternatively, it may help flush saline water and reduce any impact of salinity on a localized area (i.e., the floodplain); low flows require a smaller central channel
9. Outlet channel	• outlet channels should have coarse alluvial material for at least 50 m downstream to sustain the shape and integrity of the channel; after this standard watercourse design guidelines can be used (Golder 1998a)
10. Erosion	• use the geomorphic approach using a variety of natural measures (Golder 1998a), rapid revegetation of uplands slopes, and upstream sediment ponds
11. Salinity	• see list of saline tolerant plants in Appendix F if salinity levels are high and if revegetation is required; Appendix F is for information only, species used for wetland reclamation should be native to the oil sands region (i.e., the Central Mixed Wood Region of the Boreal Forest)

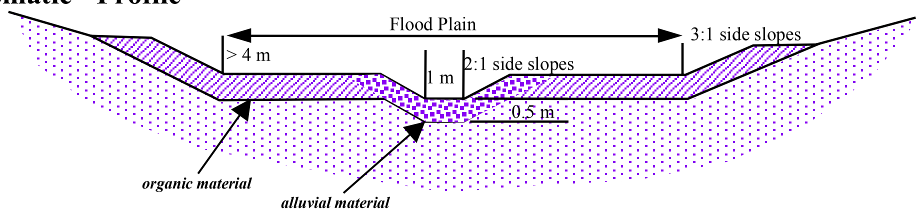
4.4.4.4 Development Approach Sheet for Flood Control Wetlands

PRIMARY FUNCTION: *Flood control, peak flow attenuation, prevention of downstream flooding, flushing of saline waters*

- At high flows, the floodplain area will retain water, thereby moderating downstream floors and enhancing the function of downstream wetlands and decreasing erosional processes in downstream streams and rivers.
- At low flows, more concentrated saline water will be restricted to the mid-channel area, limiting any adverse impacts of salts to areas within the flood plain.

Site Identification

Schematic - Profile



Site-Specific Sketch

Key Issues (see Section 4.4.4.3)	Relevant Data/Comments	Development Approach for Site-Specific Design
Watershed: Wetland ratio		•
Water Depth in the Floodplain		•
Soil/Sediment Permeability		•
Water Velocity		•
Floodplain Topography		•
Area		•
Peak Water Flow		•
Central Channel		•
Outlet Channel		•
Erosion		•
Salinity		•

4.4.5 Water Treatment Wetlands

4.4.5.1 General Description

Overview:

Water treatment wetlands improve water quality through biological (e.g., microbial and plant metabolism), chemical (e.g., photochemical, reduction-oxidation) or physical (e.g., sedimentation, volatilization, adsorption, dilution) processes. Water quality can be improved in terms of specific parameters, toxicity, etc. Constructed wetlands can treat process-affected waters and can be built according to fundamental principles of wetlands design. The initial design “driver” for a treatment wetland will be the effective treatment of the water quality parameter(s) of concern. However, treatment wetlands should be established and managed with the longer term view that they will evolve into habitat wetlands as the volume of process-affected water entering the wetland decreases over time.

Rationale:

A variety of process-affected waste waters will discharge onto the landscape after mine closure and will likely require treatment to improve water quality. In addition, some landforms such as overburden dumps may release waters that are affected by the nature of the materials in the overburden (e.g., saline or sodic materials). The principle sources of release waters are expected to be: 1) CT release water from the engineered treatment of tailings and 2) leachate from landforms such as overburden dumps or tailings sand storage areas. Whatever the source, this water will likely require treatment to remove or minimize any environmental constituents of concern such as ammonia, naphthenic acids, hydrocarbons and metals. Water treatment wetlands will be needed where release waters are expressed into the landscape.

Past research has shown that process-affected waters can be treated in wetlands (e.g., Bishay and Nix 1996). For example, acute fish toxicity can be removed (e.g., ammonia) and chronic toxicity can be depleted. Salinity levels would not be substantially altered by constructed wetlands.; however, wetlands could be designed to maximize surface water inflow relative to saline water inflow from CT deposits, thereby promoting the dilution of saline water entering the wetland.

Comments:

Basic design features of water treatment wetlands include: 1) long retention times to allow for the effective biodegradation of constituents of concern; 2) areas with water depths of 1.5 to 2 m to enhance oxygenation by wind/waves which, in turn, provides oxygen for bacterial degradation processes; 3) areas with water depths of <0.5 to allow for dense vegetation growth (plant surface area allows high densities of bacteria); and 4) elevated levels of phosphorus to stimulate bacterial growth (Bishay and Nix 1996).

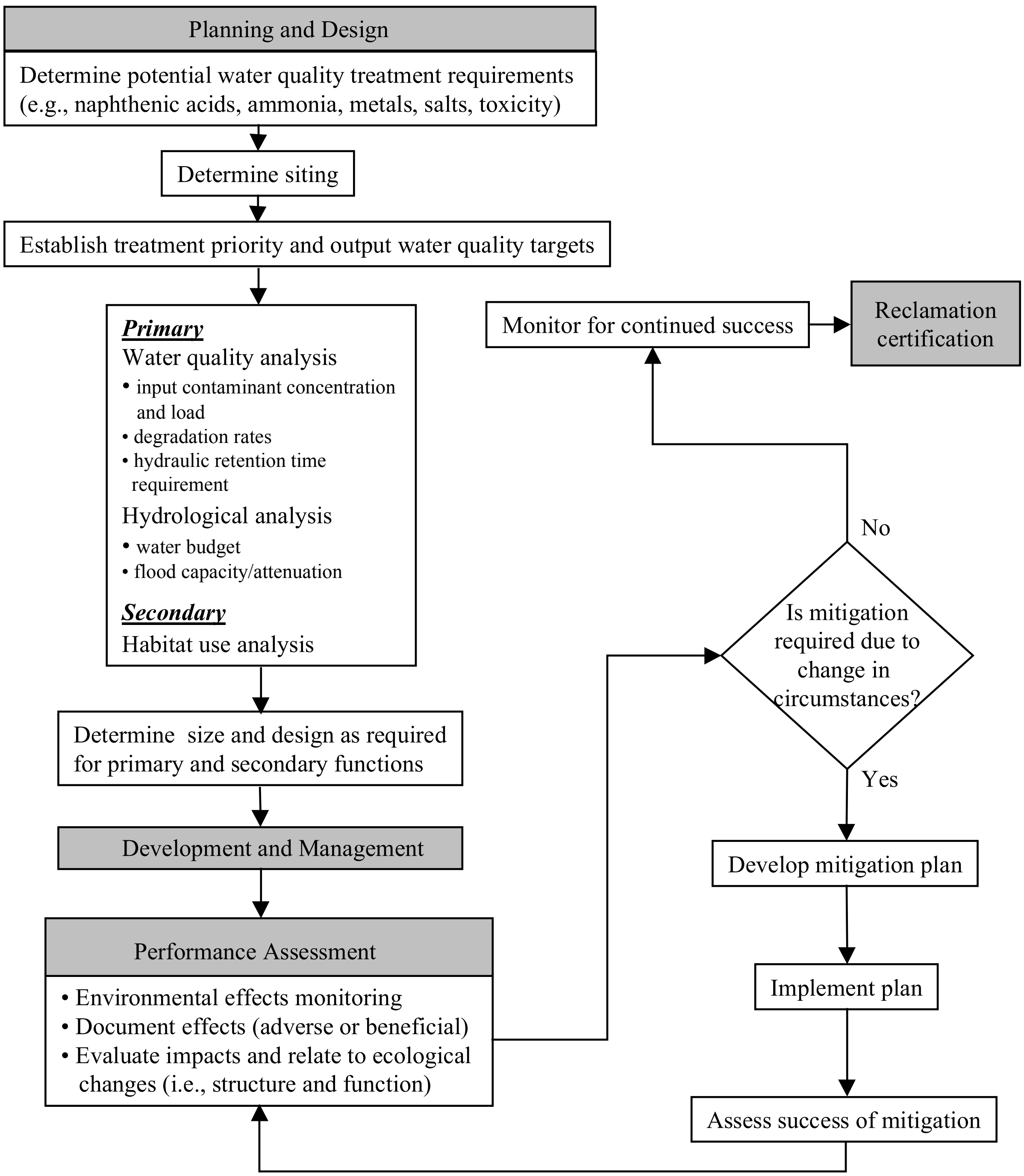
Currently, the period of time after mine closure when release waters will occur in quantities that require treatment can only be estimated; however, for some landforms (e.g., tailings sand storage areas), this period may last hundreds of years. Therefore, the sustainability of these wetlands over time is an important issue in terms of wildlife value. Wildlife habitat values will be influenced by the capability of wetlands to remove acute and chronic toxicity associated with process-affected waters.

A detailed summary of treatment wetlands and basic design parameters for dyke drainage and CT seepage waters are provided in Appendix H. There are two basic types of constructed wetlands: surface flow and subsurface flow wetlands. The constructed wetlands described in this manual are surface flow wetlands. Subsurface flow wetlands may have better performance capabilities for removal of most chemicals; however, they have generally higher capital costs and increased operational expenses (Kadlec and Knight 1996) and therefore would generally be practical only when the mine is operating.

4.4.5.2 Water Treatment Wetlands Management Flow Chart

Definition: A constructed wetland that is planned and designed to provide functions related to water quality improvement.

Objective: To provide functioning wetlands with a primary role of water treatment.



4.4.5.3 Key Issues Checklist for Water Treatment Wetlands

ISSUE	SELECTED DESIGN RECOMMENDATIONS
1. Chemicals of concern	• the key chemicals of concern for treatment wetlands include hydrocarbons (e.g., PAH's), ammonia, metals, salts and naphthenic acids
2. Configuration	• a length to width ratio of 10:1 or greater would likely increase treatment effectiveness (Kadlec and Knight 1996) • length to width ratio should be a minimum of 2:1 to treat dyke drainage and CT water (Bishay and Nix 1996) • multiple cells can enhance treatment effectiveness; a pond-wetlands system improved the treatment of dyke drainage water, however, for CT water a pond-wetlands system produced a quality of water comparable to a wetlands system alone (Bishay and Nix 1996)
3. Hydraulic Retention Time (HRT)	• time for removal of ammonia or acute toxicity is ~ 15 to 30 days (Bishay and Nix 1996) • time for removal of acute/chronic toxicity due to naphthenic acids or hydrocarbons is uncertain and likely > 1 year • Appendix H provides design recommendations for treatment of dyke drainage water and CT release water, recognizing further work is needed • controls such as temporary weirs and dams may be needed to achieve the design HRT; these structures will have to be removed at closure unless it can be shown that they are maintenance free and consistent with a sustainable wetland
4. Inflow Rate	• inflow rate in conjunction with volume of the wetland will determine the hydraulic retention time of the wetland
5. Infilling	• upstream sedimentation ponds may be required to decrease infilling and thereby to increase longevity
6. Liner	• an impermeable substrate layer (overburden or clay) should underlay a muskeg-soil amended sediment
7. Depth	• should average about 0.25 to 0.5 m in shallow areas; 0.5 to 2 m in deep areas • if above original ground level, any ponded area should be < 2 m deep and away from earth containment structures (Golder 1998a) • weirs may be required to control water depth during the first years, but should be removed before certification
8. Open Water	• open water promotes aeration of the water column and should be about 10 to 20% of the wetland area and arranged intermittently along its length (Hammer and Knight 1994)

ISSUE	SELECTED DESIGN RECOMMENDATIONS
9. Phosphorus	• increasing the size of catchment area (if possible) will increase nutrient inputs from surface water • adding phosphorus (as phosphate fertilizer) for the first few years will maximize initial treatment capability, maximum level of 100 ug/L P (Reed 1990)
10. Revegetation	• rapid revegetation may be required since the surface area of plants enhances the growth of bacteria needed to degrade chemicals and thereby promotes a rapid treatment capability • fresh wetland soils could be transferred (preferably from a donor marsh-type wetlands rather than peatlands) as a final sediment amendment to transfer roots and tubers (seed transfer, either naturally or by harvesting, would likely be less effective) • transplantings may encourage rapid colonization (pockets of transplants with a density of 1 to 4 plants/m^2) • if saline tolerant plants are required see Appendix F; otherwise, see checklists for habitat wetlands, as well as Appendix E; Appendix F is for information only, species used for wetland reclamation should be native to the oil sands region (i.e., the Central Mixed Wood Region of the Boreal Forest)
11. Winter Temperatures	• low winter temperatures may need to be compensated by greater retention times to complete treatment • a temporary weir (i.e., pre-certification) will increase winter water levels and thereby: 1) increase retention times, and 2) provide higher insulation potential (i.e., ice cover) and hence higher temperatures to encourage microbial activity
12. Fish	• a gradient of > 11% or a suitable waterfall may inhibit fish migration downstream of the outflow (Green and Salter 1987) and thereby prevent fish from migrating into water treatment wetlands

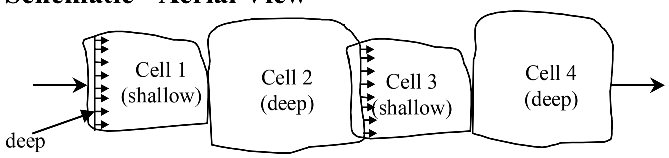
4.4.5.4 Development Approach Sheet for Water Treatment Wetlands

PRIMARY FUNCTION: *Water quality improvement*

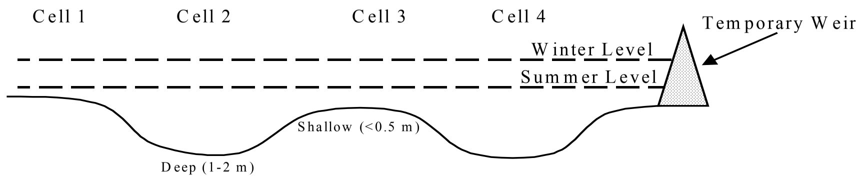
Wetlands can enhance the removal of environmental constituents of concern.

Site Identification

Schematic - Aerial View



Schematic – Profile



Site-Specific Schematic

Key Issues (see Section 4.4.5.3)	Relevant Data/Comments	Development Approach for Site-Specific Design
Chemical(s) of Concern		•
Configuration		•
Hydraulic Retention Time (HRT)		•
Inflow Rate		•
Infilling		•
Liner		•
Depth		•
Open Water		•
Phosphorus		•
Revegetation		•
Winter Temperatures		•
Fish		•
		•

4.4.6 Habitat Wetlands

4.4.6.1 General Description

Overview:

Natural wetlands in the boreal region provide an environment for various kinds of wildlife.

Habitat wetlands are created in the reclaimed landscape for their value as habitat for plants and wildlife which in turn support activities by traditional users.

Although habitat wetlands are designed with the primary function of supporting wildlife, all wetlands on the reclaimed landscape will be used by wildlife to varying degrees. However, recommendations for enhancing habitat focus on constructed (e.g., flood control, water treatment, habitat), vegetated watercourses and littoral zone wetlands. The enhancement of water treatment and, to a lesser extent, flood control wetlands will be contingent on alleviating concerns related to the potential toxicity or salinity of release waters from constructed landforms on the reclaimed landscape.

Rationale:

Although peatlands will not likely be recreated, other wetlands types (i.e., marshes and shallow open water) will be constructed to provide equivalent capability in terms of wildlife habitat (e.g., biodiversity, productivity). Marshes can provide effective habitat for wildlife.

Wetlands are dynamic, highly productive ecosystems which, in association with surrounding uplands, provide valuable habitat for a diverse array of aquatic and terrestrial wildlife species. Their value depends on factors including: vegetation structure and diversity, surrounding land use, spatial dispersion, vertical and horizontal zonation and water chemistry (Westworth 1993). It is important to note, however, that “the total duplication of natural wetlands is impossible due to the complexity of restored systems and the subtle relationships of hydrology, soils, vegetation, animal life and nutrients” (Kusler and Kentula undated). The authors also note that the restoration of habitat for ecologically sensitive animals or plants is difficult.

Comments:

Wetlands designed and constructed to function primarily as fish and wildlife habitat are anticipated to develop into semi-permanent and permanent marshes. These areas have the potential to support a relatively high diversity and abundance of wildlife species if aquatic and terrestrial environments are favourable. Historically, semi-aquatic furbearers (beaver, muskrat, river otters, mink) and ducks (dabbler and diver species) have been selected as the representative target species for aquatic habitats.

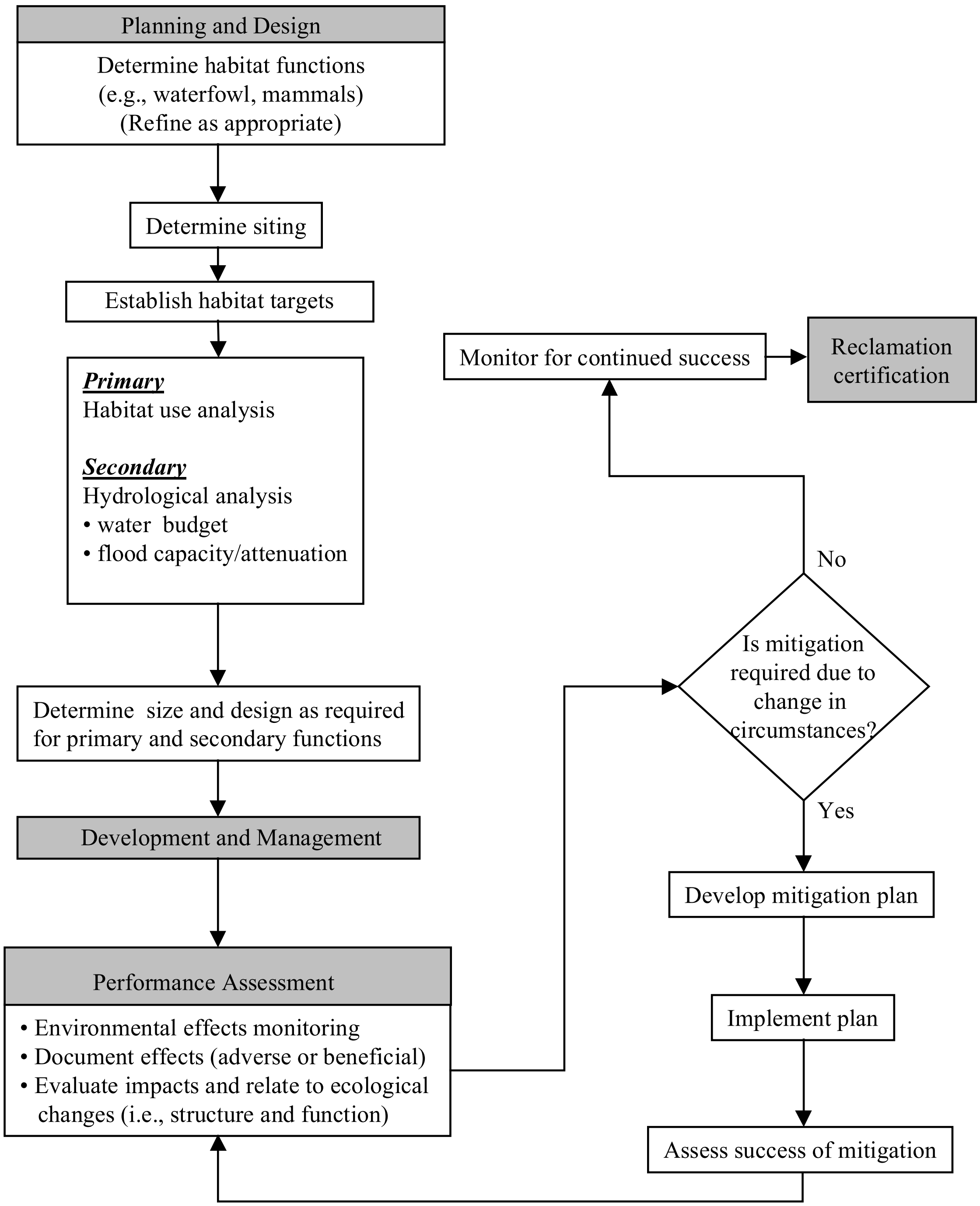
Habitat wetlands should be built within the reclaimed landscape, generally downstream from flood control wetlands. Habitat design considerations should also be part of the design for water treatment wetlands; that is, so that over time their habitat value increases as the need for treatment diminishes (i.e., toxicity lessens) and water levels recede.

Appendix E provides more detailed discussions on the habitat requirements for waterfowl and wildlife, as well as design considerations for providing habitat.

4.4.6.2 Habitat Wetlands Management Flow Chart

Definition: A constructed wetland that is planned and designed to provide functions related to habitat for plants and wildlife.

Objective: To provide functioning wetlands with a primary role of habitat value.



4.4.6.3 Key Issue Checklist for Habitat Wetlands

ISSUE	SELECTED DESIGN RECOMMENDATIONS
1. Water Level Fluctuations	• will likely occur naturally depending on the nature of the water balance; affected most notably by evapotranspiration rates, losses/gains to groundwater, and surface water inflow rates • should be encouraged in some wetlands to provide increased emergent vegetation and uplands nesting areas (K. Lumbis, pers. comm.) • flooded areas should be designed so that aquatic organisms do not become trapped as water levels recedes (i.e., no barriers, no deep areas unconnected to the main channel)

2. Bottom Contours	• bottom contours should be designed to provide:
	  • extensive littoral zone (generally <1.5 m) with some areas of deeper water – include local irregularities (Green and Salter 1987)
	  • bowl-shaped to ensure a succession of plant communities as water levels fluctuate (K. Lumbis, pers. comm.)
	  • interspersion of varying depths to provide overwintering habitat for semi-aquatic furbearers (primarily muskrat) and forage fish
	  • local irregularities to increase the interspersion of shoreline, and shallow and open water areas (Green and Salter 1987)

3. Transplantation	• transplantation is expensive; consider using this technique for only the most upstream wetlands (it may act to colonize downstream wetlands) • donor stock should be used from wetlands being removed during concurrent mine clearing operations (i.e., ecosystem transplant) • planting densities of 1 to 4 plants/m^2 established a dense stand after one year (Bishay and Nix 1996) • the transfer of imported sediments from donor wetlands can increase abundance and biodiversity (Vivian-Smith and Handel 1996)
4. Muskeg Seed Stock	• fresh muskeg provides a valuable source of peatland plant species: it may not produce comparable communities, but the plant community will not be identical to pre-development wetlands in any case; muskeg will likely create greater biodiversity compared with transplantation • sediment from donor wetlands from created marshes on reclaimed areas or from nearby natural marsh wetlands can provide a suitable wetland soil as well as a variety of plant species
5. Uplands Sediment Yield	• an average of 0.16 mm/year would provide for long-term sustainability (Golder 1998a) – to minimize yield, consider upland soils, slopes, vegetation and geomorphic protection • sedimentation ponds should be placed upstream of habitat wetlands if high yields are anticipated
6. Sediment/Soil	• 20 cm of muskeg as per terrestrial reclamation protocol will provide optimal penetration by rhizomes and roots (Hammer 1989) • pure peaty material is not recommended for wetland development (Hammer 1989) since, when flooded, it may become loose and provide inadequate support for emergent plant • a muskeg:mineral soils mix (ratio of 1.5:1; Leskiw 1998) should be applied in a layer of about 20 cm on areas with projected water depths < 45 cm (Brown and Bedford 1997)
7. Substrate	• using the least permeable overburden as substrate will enhance sustainability

ISSUE	SELECTED DESIGN RECOMMENDATIONS
8. Shoreline	• providing a variety of shoreline habitats for wildlife, including resting areas, will increase habitat edge and enhance biodiversity • provide diversity through convoluted shorelines and islands (Green and Salter 1987); small areas with no muskeg; and mounds made of sand rocks, or clay (K. Lumbis, pers. comm.) • bank slopes should be between 5H:1V to 15H:1V (Kentula et al. 1992) with the majority at the flatter end of the range (Brown 1991)
9. Waterfowl and Muskrat	• muskrat habitat is compatible with waterfowl (Concord Scientific 1989) • a 1:1 ratio of open water to vegetated areas is ideal for a diversity of waterfowl (Weller 1978) as well as other animals (J. Martin, pers. comm.) • grassland areas in the uplands are optimum for nesting of some species (the possibility exists for shallow water treatment wetlands cells to evolve into seasonal grasslands) • relatively stable water levels are required to maintain beaver and muskrat populations (J. Martin, pers. comm.)
10. Aquatic Plants	• depths of 0.5 m to 3 m and a minimum spring depth of 60 cm are recommended, especially if summer inflows are expected to be low (K. Lumbis, pers. comm.) • establishment of emergent aquatic macrophytes should be promoted – depths of <1 m (0.1 to 0.5 m); submergent macrophytes – depths of 2 to 3m (also provides a valuable food resource for moose)
11. Traditional Plants	• aboriginal peoples should be involved in determining appropriate species, describing habitat requirements, selecting donor sites and researching methods for transplanting and seeding • further information and research needed on methods to establish traditional plants) • see Appendix I for a list of plants
12. Biodiversity	• wetlands should be spaced <1.2 to 1.6 km apart (Proctor et al. 1993; cited by Bovar unpub.) • topographic landforms provide shelter (e.g., small hills, islands) – include as many habitat types in the uplands as possible • a mixture of grasslands and forests should be placed in upland areas • the development of diverse and robust emergent, submergent and floating aquatic plants is critical to optimize habitat values and diversity
13. Beaver	• beaver prefer streams over lakes and prefer deciduous, white spruce and willow-swamp habitat (Searing 1979) • beaver habitat is characterized by irregular shorelines, heavy-textured banks, upland slopes less than 25%: low stream gradient (<15%), narrow width (<5m), U-shaped valleys, distinct channel morphology allowing the establishment of pools behind dams, banks with less than 45° slope, bank height < 2 m and bank material consisting of clay soils (Bovar 1996).
14. Fish	• enhancement for game fish habitat may be restricted to waters downstream from end pit lakes • depths of 2 to 3 m (0.1 m to 3 m) provide overwintering pools • see Golder 1998a for more details and standards for fish habitat

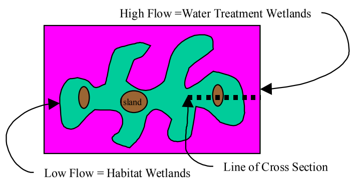
4.4.6.4 Development Approach Sheet for Habitat Wetlands

PRIMARY FUNCTION: *Habitat for plants, waterfowl, wildlife and fish*

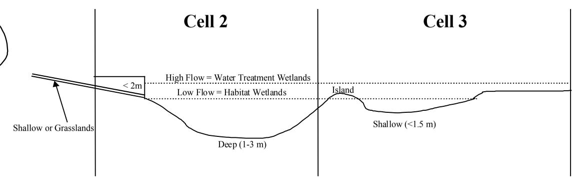
- a variety of physical/chemical/topographic conditions will provide for a diversity of plants, waterfowl, fish and other animals
- traditional uses by aboriginal peoples also need to be considered
- a design for water treatment capabilities may also be combined with habitat functions which dominate at low inflow rates of process-affected waters

Site Identification

Schematic – Aerial View



Schematic – Profile



Site-Specific Schematic

Key Issues (see Section 4.4.6.3)	Relevant Data/Comments	Development Approach for Site-Specific Design
Water Level Fluctuations		•
Bottom Contours		•
Transplantation		•
Muskeg Seed Stock		•
Uplands Sediment Yield		•
Sediment/Soil		•
Substrate		•
Shoreline		•
Waterfowl and Muskrat		•
Aquatic Plants		•
Traditional Plants		•
Biodiversity		•
Beaver		•
Fish		•
		•

4.4.7 Vegetated Watercourses

4.4.7.1 General Description

Overview

Vegetated watercourses are designed on the reclaimed landscape for the purpose of conveying water to wetlands, between wetlands, and offsite.

There are various types of vegetated watercourses evident in nature, offering a reliable conveyance for a broad range of environmental conditions. A well established vegetated watercourse can handle extreme events with minimal risk of failure. Vegetated watercourses will support wetland vegetation and are more robust to flooding since they will often include dense communities of bulrushes, willows, tall reed grasses (Golder 1998a).

Rationale:

Streams and their riparian areas are probably the most important waterbodies for semi-aquatic furbearers such as beavers, muskrats, mink and river otters (Searing 1979). Riparian areas are wetlands associated with running water systems found along rivers, streams and drainage ways (Golder 1998a). Riparian areas can also include the transition zone around a waterbody such as a marsh or lake.

Riparian areas provide important habitats for breeding birds; species richness and diversity was greatest in dogwood-balsam poplar-aspen poplar stands – a riparian community type (Golder 1998a). These wetlands have the potential to provide valuable food resources (browse species) and critical travel corridors for moose and other ungulates within a reclaimed landscape. However, their value as travel corridors is contingent on their integration with existing natural travel corridors (e.g., river valleys). The habitat value of other wetlands types would be enhanced if wildlife can move from one to another. Wetlands connected hydrologically by surface water, including intermittent connections, are the most valuable (Golet 1976). The connection of different wetlands/habitats enhances biodiversity (see Appendix E).

Vegetated watercourses will be required to convey water across the reclaimed landscape and between wetlands and other waterbodies. Erosion protection is supplied by partially decomposed vegetation, tree and shrub roots and debris. These types of channels are capable of providing conveyance for relatively large drainage areas because of the flow resistance and energy dissipation provided by the vegetation (Golder 1998a).

Comments:

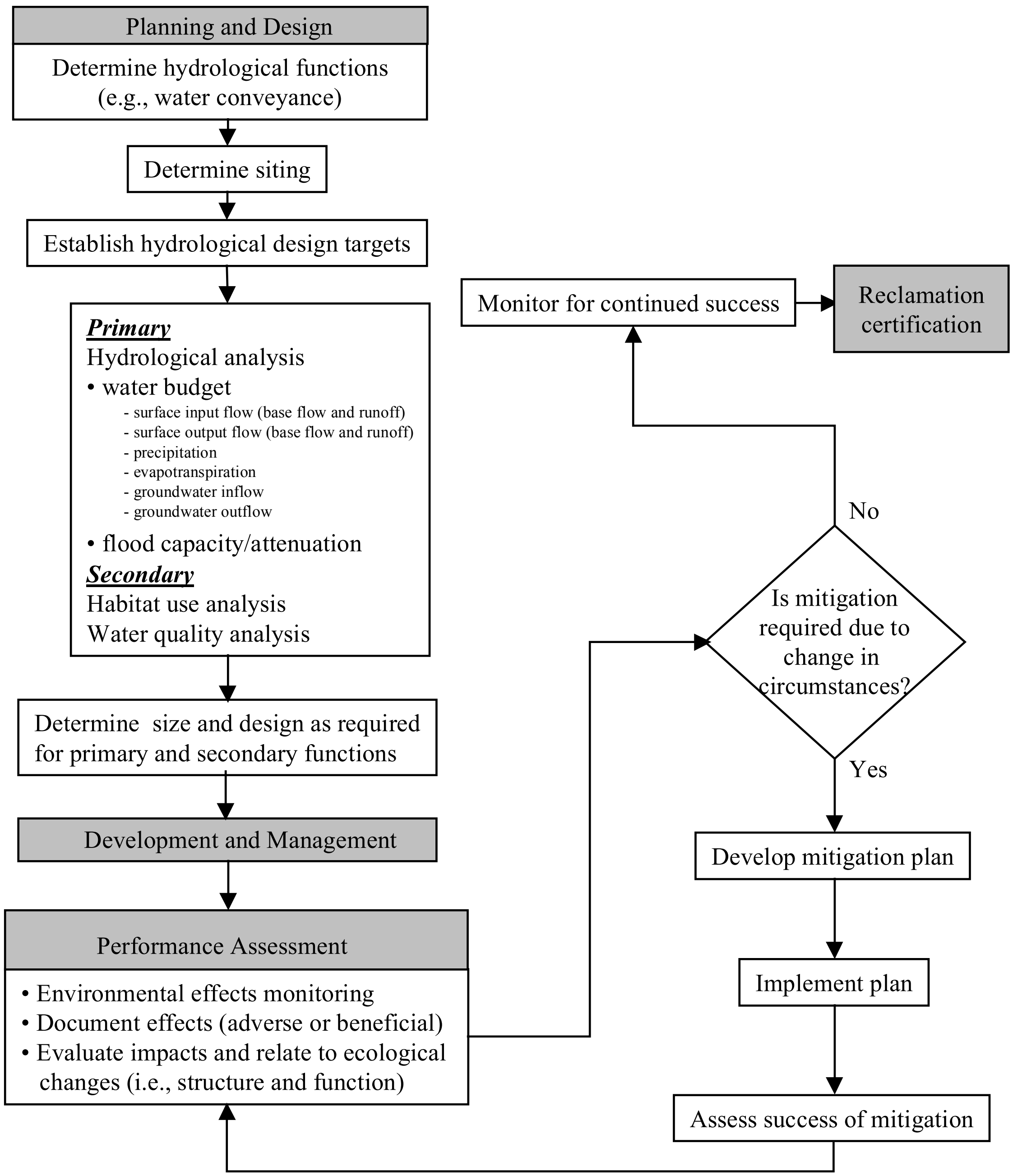
Primary design considerations will be hydrological. The proposed design of vegetated waterways is based on replicating the geomorphic character of natural systems (Golder 1998a). Permissible velocity methods and maximum tractive force methods should be used to check the design; therefore, this type is referred to as "geomorphic vegetated watercourses" to differentiate them from the conventional "grass waterways". Geomorphic vegetated watercourses incorporate the robust features of natural systems.

The approach would be that biological enhancements would occur along wetland connections. This could include establishing vegetation (e.g., sedges, grasses, bulrushes, cattails, shrubs, trees such as willow, alder and poplar) along the edge; creating smaller pockets of deeper water along intermittent streams; allowing beaver dams, where appropriate, to remain; and nesting boxes for species that utilize stream habitats, etc.

4.4.7.2 Vegetated Watercourses Management Flow Chart

Definition: Watercourses that are vegetated channels that convey water to wetlands, between wetlands, and offsite; they also provide valuable riparian habitat.

Objective: To provide routes for water to move across the landscape and into the receiving environment while also providing habitat functions, including connectivity.



4.4.7.3 Key Issues Checklist for Vegetated Watercourses

ISSUE	SELECTED DESIGN RECOMMENDATIONS
1. Slopes	• channel side slopes should be: maximum of 4H:1V in sandy soils, 2.5H:1V for overburden, 1.5H:1V for clay where channel depth is <1 m (Golder 1998a) • lower reaches should be underdesigned to allow flooding during peak flows
2. Channel Form	• "two level" channels would mimic many natural streams (i.e., a central channel and adjacent bank surrounded by a wider channel and second bank)

3. Riparian Vegetation	• riparian vegetation should be established as follows:
	  • above the banks: preferred ungulate browse species (e.g., red osier dogwood, saskatoon, choke cherry, willow)
	  • above the banks: balsam poplar, alder, etc. to enhance habitat value and wildlife utilization of these areas
	  • on the banks: willow, etc. (Golder 1998a)
	• soil should be replaced on riparian areas down to the water level to facilitate vegetation establishment and diversity
	• a thick zone of rock/cobble should be used on steeper gradients (Golder 1998a)

4. Erosion	• vegetated watercourses may need to perform before vegetation is adequately established (Golder 1988a) • extra organic stock substrates should be added from existing wetlands to enhance plant colonization • watercourse channels should be developed: 1) after peak flows (i.e., freshet); and 2) before drainage pattern is established (i.e., use temporary diversion systems) • temporary berms (i.e., earth) or check dams with live willow poles (Golder 1998a) should be used to moderate peak flows • riprap or sacrificial plugs should be used as outlined in Golder (1998a)
5. Fish	• vegetated watercourses may support forage fish, but the support of game fish is not a design objective for most watercourses • selected locations such as outflows from end pit lakes may need to support game fish - see details in Golder (1998a)

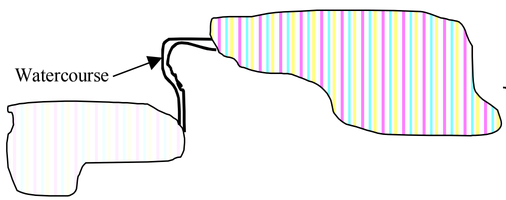
4.4.7.4 Development Approach Sheet for Vegetated Watercourses

PRIMARY FUNCTION: *Water conveyance and habitat*

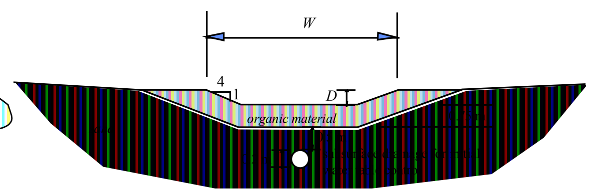
- drainage is essential to control water levels and hence provide sustainable plant and animal communities
- connectivity between wetlands enhances habitat values
- associated riparian areas provide aquatic and terrestrial wildlife habitat as well as wildlife travel corridors

Site Identification

Schematic – Aerial View



Schematic – Profile



Site-Specific Schematic

Key Issue (see Section 4.4.7.3)	Relevant Data/Comments	Development Approach for Site-Specific Design
Slopes		•
Flooding		•
Riparian Vegetation		•
Erosion		•
Fish		•
		•

4.4.8 Littoral Zones in End Pit Lakes

4.4.8.1 General Description

Overview:

Littoral zone wetlands will be designed along the shores of reclaimed end pit lakes.

Littoral zones comprise shallow areas (< 2m deep) with emergent and submergent macrophytes. This zone receives more light and nutrients, thereby increasing plant and animal productivity. Littoral zones provide valuable wildlife and fisheries habitat. Littoral zones also provide hydrological (i.e., shoreline protection) and water treatment functions.

Rationale:

The most prevalent form of natural erosion protection in small shallow lakes (i.e., < 3 m deep or < 800 m wide) is the establishment of vegetation. In larger lakes, wave energy exceeds this protection capacity (Golder 1998a); therefore, physical protection will also be needed.

In terms of habitat, the littoral zone constitutes a major source of organic matter (i.e., plant growth) that contributes significantly to lake productivity (i.e., plant and animal abundance) and its overall ecological functions (Wetzel 1975). Design considerations to enhance fish and wildlife habitat in littoral zones are detailed in Appendix E.

In terms of water treatment capability, oxygenated shallow areas increase ecosystem stability and the ability of microbes to biodegrade process-affected water from upstream discharges on the reclaimed landforms (Nix et al. 1995) or from tailings (if they are deposited in an end pit lake). A littoral zone with no underlying tailings layer may provide a necessary contingency water treatment function in this event and act to protect downstream receiving waterbodies.

Comments:

The size of the littoral zone is critical to the productivity and biological colonization of the entire lake. In fish-bearing lakes in the region, this zone ranges between 10 to 30% of the total surface area. Notwithstanding this broad role in the ecosystem, fish yield will likely be limited by phosphorus rather than littoral zone size. However, it is expected that development of the biological community littoral zone will speed up biodegradation process and enhance water treatment capabilities (Nix et al. 1991).

Aquatic macrophytes in the littoral zone of existing lakes in the oil sands region are affected by substrate size and texture, wave action, water depth and turbidity (Mitchell and Prepas 1990). Additional factors which affect aquatic vegetation species composition, distribution and relative abundance are: depths >1.5 m inhibit growth; wave action damages most emergent, free floating or floating-leaved macrophytes; ice scouring during spring break-up can eliminate macrophyte production in areas up to 1 m deep (consequently, macrophytes grow along shorelines of small lakes and at shallower depths along protected shorelines of large lakes (Golder 1998a)).

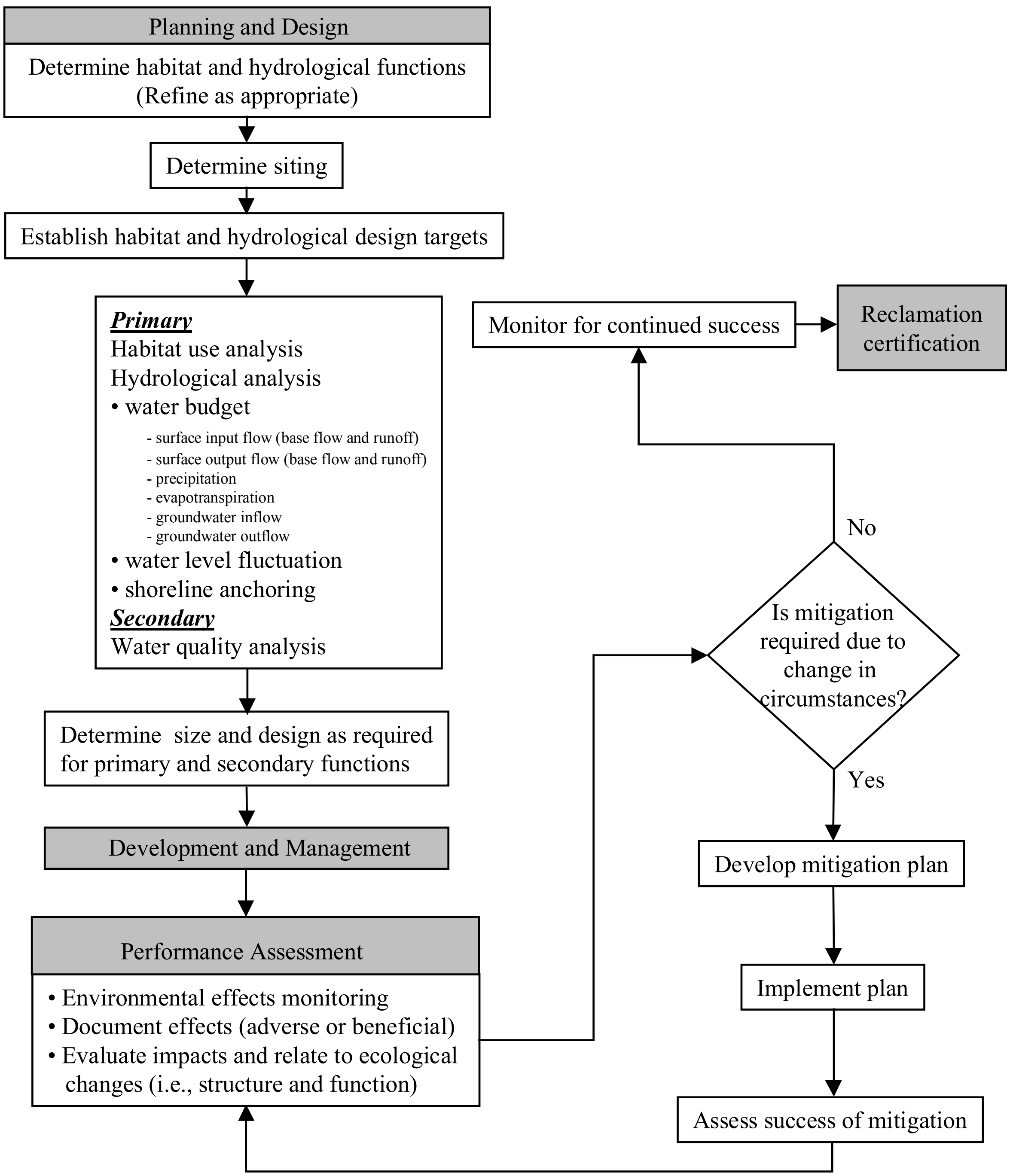
Appendix E provides further information on design considerations for littoral zones in lakes.

A joint industry/government/public stakeholder committee has been established to develop guidelines for the reclamation of end pit lakes. The work of this committee will provide further recommendations respecting littoral zones.

4.4.8.2 Littoral Zones Management Flow Chart

Definition: Shallow areas (< 2m) along the shores of reclaimed lakes with emergent and submergent macrophytes.

Objective: To provide littoral zones within larger waterbodies (e.g., lakes) for habitat functions as well as hydrological (e.g., shoreline protection) and water treatment functions.



4.4.8.3 Key Issues Checklist for Littoral Zones

Issue	Selected Design Recommendations
1. Extent	• littoral zone should be at least 20% of the lake (i.e., < 3 m); that is, similar to other regional lakes to optimize fish habitat (J. Martin, pers. comm.)
2. Depths	• establishment of aquatic macrophytes is related to depth: emergent aquatic macrophytes – depths of <1 m (0.1 to 0.5 m); submergent macrophytes – maximum depths of 2 to 3m
3. Bottom Contours	• bottom contours should provide: irregular, narrow to wide shoreline shelves; gradual slopes (11 to 22%); average depths of 0.5 to 1.5 m • steeper slopes (44 to 67%) along some parts of the shoreline should be used to provide access to deep water and limit plant growth (Green and Salter 1987) • reefs will promote establishment of aquatic plants
4. Shoreline	• littoral zones should provide a variety of shoreline characteristics (e.g., emergent vegetation, waterfowl cover, nesting sites) • irregular shorelines with shallow bays have the potential to develop into marsh habitats. • mudflats/gravel bars provide habitat (shorebird foraging, nesting sites)
5. Special Waterfowl	• islands along the foreshore provide valuable habitat for wetland bird species: design criteria for the creation of nesting islands for raptors and colonial birds (e.g., American white pelican, double-crested cormorant, common tern, osprey, eagle) are found in Multi-Species Habitat Enhancement Techniques (Ewaschuk and Gurr 1992) • elevated nesting platforms can provide secure nesting areas
6. Sediment/Soil	• a muskeg:mineral soils mix (ratio of 1.5:1; Leskiw 1998) should be applied in a layer of about 20 cm on areas with projected water depths < 45 cm (Brown and Bedford 1997) • native plants could be encouraged through the addition of sediment material from nearby natural wetlands or donor wetlands
7. Revegetation	• if needed, see notes for habitat wetlands

8. Habitat Diversity	• habitat diversity can be promoted in a variety of ways:
	  • diversity of upland areas (e.g., grasslands, forests)
	  • irregular shorelines with the development of shallow bays, shoals mudflats, sand bars and islands
	  • irregular bottom sediment/substrate (e.g., rocks, gravel, sand, overburden, muskeg)
	  • underwater structures such as reefs utilizing natural or surplus material (e.g., waste rock, logs/stumps, machinery, tires)
	  • a diversity of quiet water and wave susceptible areas
	  • elevated nesting platforms
	• Appendix E provides further information on habitat design considerations for littoral zones

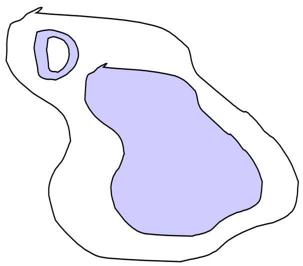
4.4.8.4 Development Approach Sheet for Littoral Zones

PRIMARY FUNCTION: *Complement both water treatment and habitat functions of end pit lakes*

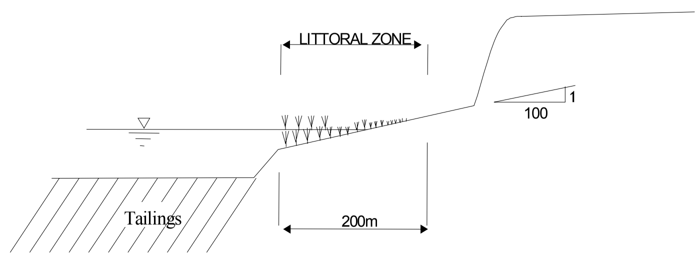
- rearing areas for non-sport fish species
- water treatment functions in aerobic shoreline (i.e., littoral areas) may be needed as a contingency to degrade potential inputs of chemicals from upstream drainage systems (e.g., CT landforms), especially if anaerobic conditions prevail in lake surface water.

Site Identification

Schematic – Aerial View



Schematic – Profile



Site-Specific Schematic

Key Issues (see Section 4.4.8.3)	Relevant Data/Comments	Development Approach for Site-Specific Design
Extent		•
Depths		•
Bottom Contours		•
Shoreline		•
Special Waterfowl		•
Sediment/Soil		•
Revegetation		•
Habitat Diversity		•
		•

5. WETLAND PERFORMANCE ASSESSMENT

5.1 Introduction

Performance assessment evaluates the establishment and development of wetlands on reclaimed areas. Performance assessment, as used in this guideline, means the monitoring of physical, chemical, and biological factors and the evaluation of predicted performance or target values with observed performance and trends, as well as draft interim reclamation criteria (see Section 6).

Performance assessments are needed to determine whether a wetland is meeting its intended function (e.g., flood control, water treatment, or habitat) and whether it is "free-to-evolve." Criteria for assessing the performance and success of wetland reclamation must be site specific, measurable and based on a clear understanding of the functions to be provided. Selection of parameters for monitoring and assessment is currently confounded by the inherent inability of an immature wetland to exhibit functional equivalency to an older system (i.e., functions develop over long periods). In addition, reclaimed wetlands may have no clear analogue in the region (e.g., saline wetlands on CT deposits). Nevertheless, it will be possible to evaluate reclaimed wetlands. Social values such as traditional land uses will need to be considered in the evaluation.

Performance will be considered "successful" when the values for a particular characteristic fall within an acceptable range of target values for that characteristic (e.g., design values or values from benchmark/reference wetlands; interim criteria). Performance assessments can also be done during the operation in terms of the measurement of specific functions (e.g., water quality improvement targets in a water treatment wetland) or the documentation of trends in particular parameters over time (e.g., is the development of a wetland, as measured by particular parameters, occurring at the expected rate or does it appear to be falling short such that remedial measures may need to be evaluated).

The creation of wetlands on reclaimed landscapes must recognize that a period of time will be required to establish them. The establishment period is expected to be in the order of 10 to 15 years. At that point, the system should be set on a path of ecological succession and development and be "free to evolve.". Wetland systems, including watercourses, should not require long-term maintenance and management.

Specific performance assessment criteria have not been specified at the present time since target values and reclamation criteria require further development. However, Section 6 (Reclamation Certification) provides an overview of general interim reclamation criteria.

5.2 Performance Assessment Framework

Table 5.1 provides an initial framework for performance assessment based on:

1. key issues (i.e., hydrological, physical, biological, chemical);
2. performance indicators;
3. measurement endpoints;
4. performance assessment targets;
5. potential cause of failures;
6. prevention of failures through initial design;
7. mitigation of failures (if they occur) through adaptive management.

The selection of measurement endpoints and the establishment of acceptable variance from the target values will require further discussion among industry, government, local aboriginal peoples and public stakeholders. With respect to ecological endpoints, which will be very important in wetland evaluation, a number of matters will need to be considered, including:

1. selection of endpoints (i.e., sensitivity of the endpoint, ecological relevance, practical considerations, societal and aboriginal values);
2. selection of endpoint properties based on the biological level of organization (i.e., organism, population, community, ecosystem);
3. selection of the acceptable level of variance of the endpoint property (e.g., % difference in growth of a particular population compared to a reference or benchmark site).

Suter et al. (1994) and Sample et al. (1998) provide methods and procedures to deal with ecological endpoints, ecological risk assessment and benchmarks.

Table 5.1 Performance Assessment Key Issues

Key Issue	Indicators	Measurement End-points	Performance Assessment Target[1]	Potential Cause of Failure	Prevention (Initial Design)	Potential Adaptive Management Techniques
Hydrological	Infiltration	• water depth • outflows << inflows	• vary with wetlands type, see footnote	• soil permeability • watershed size and configuration • inappropriate placement in relation to groundwater regime	• design according to substrate permeability in relation to drainage/water flows • use of liners	• install outflow streams to maintain a more realistic (low) water level • build berms to retain more water and/or redirect flow to increase mean water depth if too shallow
	Water Balance	• storage volume • retention time • water depth • water level fluctuation • hydroperiod • inflow/outflow	• vary with wetlands type, see footnote	• blockage of channels • uncertainty associated with water balance modeling • higher than anticipated flux rates (e.g., CT seepage water)	• appropriate number and size of wetlands • area and location of upland cover • basin morphology and watershed design • appropriate uplands vegetation	• build diversion works to control peak flows during flooding • alter ratio of wetlands to uplands to change storage capacity
	Water Conveyance	• channel integrity • watercourse flow rates	• see footnote	• blockage • subsidence • uncertainty associated with water balance modeling	• appropriate channel design • establish vegetation for bank stability • appropriate substrate type	• self-armouring and erosion resistant vegetation • remove blockages (e.g., beaver dams)
Physical	Infilling and Sedimentation	• watershed sediment yield • detritus accumulation rate	• predicted lifetime (e.g., greater than time required for treatment, etc.) • vegetation performance • trend for sediment accumulation	• uplands erosion • inadequate erosion control (e.g., vegetation cover, slopes, soil materials)	• deep zones near inputs of wetlands to accumulate majority of sediment • aggressive erosion control	• Dredge and reclaim • sedimentation ponds • repair of eroded surfaces
	Wetlands Substrate Characteristics	• hydraulic conductivity • organic carbon • salinity	• plant growth and diversity • benthic community	• compaction • poor substrate quality	• cap underlying material (e.g., CT, • mix muskeg with mine materials or capping materials to yield suitable soil quality	• add muskeg material • nutrient additions • dredge and replace substrate
	Wetlands Subsidence	• Elevation • Water depth	• see footnote	• improper compaction or placement of substrate material • unknown settling characteristics	• assessment of settling rates • compaction for landscape stability	• infilling with suitable materials
	Avulsion (i.e., formation of new channels)	• flooding • channel changes	• minimal avulsion • retain wetlands functions	• flooding • channel blockage • subsidence	• appropriate channel design and gradient • appropriate design for basin morphology and watershed • build large flood plains	• self-armouring and erosion resistant vegetation • remove blockages (e.g., beaver dams)
	Bank or Shoreline Erosion and/or Siltation	• channel integrity or shoreline surveys with permanent reference points	• minimal erosion • vegetation establishment	• inappropriate substrate • higher flux rates than anticipated • inadequate vegetation cover • excessive wave action • ice movement (End Pit Lake)	• design streams for large events • design channel to be in-regime • use proper armour and/or self-armouring stream beds • design channels to inset into small valleys (i.e., avoid perched channels or levees) • use islands as breakwaters to protect littoral zones • design sheltered bays	• re-armour shorelines • construct new breakwaters • shoreline re-vegetation

Key Issue	Indicators	Measurement End-points	Performance Assessment Target[1]	Potential Cause of Failure	Prevention (Initial Design)	Potential Adaptive Management Techniques
Biological	Plant Diversity and Community	• native species • traditional use species • percent cover • undesirable species • species composition, abundance and diversity	• comparisons against bench-marks using existing ecosites (i.e., reference wetlands) • reference wetlands should encompass a range of values	• unfavourable hydrology (i.e., excessive or insufficient water) • unsuitable hydroperiod • unsuitable soils • salinity intolerance • toxicity • disease • unsuitable vegetation selection • invasive species	• appropriate water level fluctuations • suitable soils • plant species with a range of appropriate salinity tolerances • utilization of native seeds • appropriate water quality • soils and seed bank transfer from donor sites • use traditional knowledge	• fertilizer application (i.e., adjust nutrient ratios) • control undesirable species • reassess site quality of areas with poor vegetation cover and supplement with additional and appropriate plantings • import saline tolerant plants (e.g., La Saline Lake)
	Plankton	• phytoplankton and zooplankton • species composition, abundance and diversity	• as above	• poor water quality (e.g., chemicals) • low nutrient levels • salinity intolerance • toxicity • disease	• ensure a diversity of wetlands • understand cause(s) of toxicity process-affected waters and design accordingly (see "Prevention" under "Chemical")	• see "Adaptive Management Techniques" in Chemicals section • inoculations from donor wetlands • supplement with nutrient(s)
	Invertebrate Diversity and Community	• species composition, abundance and diversity	• as above	• lack of development of food chain • unfavourable hydrology (e.g., extended dry periods) • unfavourable substrate/sediment • lack of detrital food • poor water quality (eg, chemicals, DO • disease	• as above	• as above
	Fish and Wildlife Diversity and Community	• species composition, abundance and diversity • undesirable species • traditional use species • amphibians	• as above	• poor water quality • lack of critical habitat • low or high nutrient levels • disease • lack of diversity	• diversity and connectivity of wetlands • appropriate uplands habitat	• see Appendix E regarding wildlife and fish • take advantage of opportunities to enhance habitats (e.g., utilize waste materials from other leases)
Chemical	Salinity Regime	• conductivity • major ions/total dissolved solids (TDS)	• < 1,500 mg TDS /L at confluence with receiving water bodies (Env. Canada 1985) • refer to appropriate regulatory guidelines	• insufficient flushing or dilution • higher than anticipated release rates of saline water	• wetlands associated with CT materials should have shorter HRT or an increased drainage basin • deeper drainage channels with greater gradients	• establish salt tolerant plants
	Toxicity as a result of: - ammonia - metals - naphthenic acids - salinity	• acute and chronic toxicity (lab and field tests) • concentrations of specific chemicals • field surveys to assess community structure for various trophic levels and population changes of various taxa; comparisons with reference sites	• toxicity of water within wetlands, see footnote • toxicity of receiving water, see footnote • follow provincial and federal guidelines for the protection of aquatic life • follow site-specific risk based concentrations (RBC) • assess bioaccumulation rates through analysis of tissue	• insufficient retention time • high chemical input rates • insufficient vegetation cover (they provide a surface for microbes) • dissolved oxygen too low (needed to remove organics and ammonia) • dissolved oxygen too high (anoxic conditions favour metal removal) • lack of nutrients needed to support microbes (e.g., nitrogen, phosphorus, sulphate) • low winter temperatures (i.e., slow microbial degradation rates)	• larger wetlands to increase the retention times • ensure hydrology meets needs of vegetation • ensure sufficient open water areas for aeration • add muskeg to promote metals binding to soil/sediment (i.e., reduce bioavailability) and anaerobic sediments • higher water levels to increase winter temperatures (i.e., enhance insulating effects of ice cover) • design wetlands to minimize channelization (i.e., intersperse with deep areas)	• dredge deep channels against the flow of water to decrease channelization • modify water volumes and frequency to enhance vegetation growth (i.e., channel diversions) • increase or decrease open water areas by dredging/infilling (ie., to change aeration) • add nutrients (i.e., fertilizer) • add more organic matter to sediments (i.e., muskeg) • redirect surface runoff flows to either increase or decrease retention times of process-affected water • add berms to increase water levels and retention times

[1] Performance assessment guidelines are generally not specified since reclamation criteria are not yet developed. Any assessment of "success" will be a range of values with an acceptable deviation from target characteristics (e.g., reference wetlands). Furthermore, assessment will need to incorporate trend evaluation (is it trending toward an acceptable criteria) and biological bench-mark concepts (i.e., is there some threshold).

5.3 Monitoring

Although performance assessment and reclamation criteria require further development, wetlands will typically be monitored for a number of parameters in order to characterize the status of the wetland and to provide trend evaluation to determine if conditions are improving or trending to acceptable targets. Table 5.2 provides a list of suggested parameters for monitoring. The specifics of any monitoring program will need to consider the wetland type, as well as the objectives and methods of the program (i.e., sampling methods, locations, frequency).

Table 5.2 Suggested Monitoring Parameters for Wetlands

Water quality Dissolved oxygen (DO) (seasonal and winter) Temperature Conductivity Total dissolved solids (TDS) Major ions pH Biological Oxygen Demand (BOD) Total Suspended Solids (TSS) Turbidity Nitrogen (nitrate + nitrite, ammonia, Kjeldahl) Phosphorus (dissolved, total) Chlorophyll a Sulphides Metals Naphthenic acids, PAH's, phenolics Other organics Toxicity (acute, chronic)	Hydrology Inflow rate (surface water, groundwater) Outflow rate (surface water, groundwater) Evaporation Evapotranspiration Precipitation Flow distribution/pattern Peak flows/flooding (timing, extent, duration) Hydroperiod (seasonal water level pattern) Hydraulic retention time (HRT)
Sediments Redox potential Salinity PAH's Metals pH Organic matter Texture Toxicity (acute, chronic)	Biology Composition, abundance, diversity of: • Phytoplankton, Zooplankton • Benthic invertebrates • Wildlife • Fish • Vegetation • Traditional use species
Physical Sedimentation rate Channel/shoreline stability and erosion	

6. RECLAMATION CERTIFICATION

> The information presented in this section is general in nature. It provides a preliminary discussion of the reclamation certification process, information requirements for certification applications and draft interim reclamation criteria for wetlands. The Oil Sands Wetlands Working Group recognized the need for further work with respect to the reclamation certification for wetlands, in particular the development of reclamation criteria.

6.1 General

The *Environmental Protection and Enhancement Act* (EPEA) requires an operator to conserve and reclaim land disturbed or affected by an industrial activity such as an oil sands mine and to obtain a reclamation certificate. EPEA also requires the operator of an oil sands mine to apply for and obtain an approval for the opening up, operation and reclamation of a mine. In addition, activities involving the creation of wetlands are subject to review and approval under the *Water Act* and its regulations. The administration of approvals under the *Water Act* and surface dispositions under the *Public Lands Act* will be closely tied to and coordinated with the reclamation certification process under EPEA.

6.2 The Objective of Conservation and Reclamation

Under EPEA, the *Conservation and Reclamation Regulation* establishes the objective of reclamation as the return of equivalent land capability. The return of equivalent land capability means that the ability of land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that individual land uses will not necessarily be identical. Land capability is the ability of land to support a given land use (e.g., agriculture, forestry, wildlife habitat, recreation, etc.) based on an evaluation of the physical, chemical and biological characteristics of the land, including landscape (i.e., topography, drainage, hydrology), soils and vegetation.

The objective of equivalent land capability provides for sustained levels of use at least equivalent to those that existed prior to development. The concept provides for flexibility such that individual land capabilities and land uses may change, but overall land capability and land use will be equivalent to pre-disturbance conditions. As a result, reclaimed landscapes may be very similar to pre-disturbance conditions or may have areas of the landscape that are relatively different compared to pre-disturbance conditions. In the latter case, these areas should be characteristic of similar landscape types in the region.

The return of equivalent land capability allows for a variety of end land uses on reclaimed landscapes, including uses associated with wetlands. Wetlands are recognized as integral parts of the reclaimed landscape and can support uses such as habitat for plants, wildlife and fish; recreation; traditional use (e.g., hunting, trapping, medicines, cultural values); and general community hunting, fishing, and trapping.

6.3 Review Process

An oil sands operator must obtain a reclamation certificate to demonstrate that reclamation has been successful. If specific criteria or land capability evaluation procedures are available they are used to assess reclamation. In the absence of these, an evaluation of the reclaimed wetland would be undertaken and would include consideration of:

1. physical, chemical and biological characteristics of the reclaimed wetland, including integration with the adjacent landscape;

2. compliance with the EPEA approval (i.e., including the plans in the application for approval as modified by any approval conditions that may apply, as well as the land capability and end land use goals in the application);

3. adherence to the approach for wetland establishment outlined in this guideline;

4. consideration of the draft interim reclamation criteria.

EPEA and it regulations provide the regulatory framework for reclamation. Reclamation of disturbed land to wetlands will require an application for approval containing the information needed to evaluate the proposed wetland. When reclamation of the wetland is considered complete, the operator will have to apply for and obtain a reclamation certificate. General information requirements are listed in the *Conservation and Reclamation Regulation*. On submission of the application for a certificate, regulatory staff from the required disciplines would review the application, conduct site inspections and provide recommendations to the Reclamation Inspector who would make a decision.

6.4 Information Requirements

The general information requirements for a reclamation certificate application are outlined in section 14 of the *Conservation and Reclamation Regulation*:

1. a map, with references to legal boundaries, showing the land for which the certificate is being requested and the adjacent land use;
2. particulars of the characteristics and properties of the conserved and reclaimed land including topography, drainage, soils, vegetation, and land capability;
3. documentation of conservation and reclamation procedures;
4. documentation of the history of surface disturbance;
5. documentation of and justification for any surface improvements to be left on the conserved and reclaimed land and written acceptance of the improvements by the owner of the land;
6. a declaration that the operator has complied with:
   - (i) all terms and conditions of any applicable approval, Environmental Protection Order, or Enforcement Order;
   - (ii) the directions of an inspector or the Director, and;
   - (iii) any applicable standards or criteria established under Section 3(1);
7. the name, address and telephone number of all of the owners of the land;
8. particulars of any surface lease or right of entry order for the land;
9. a description of any substances present as a result of the operator's activity on the land and a description of the nature and extent of the adverse effect caused by the presence of the substance;
10. particulars of any remedial measures taken with respect to a substance referred to in 9;
11. any additional information required by an information document or requested by the Director.

In addition to the general information requirements listed above, an application for a reclamation certificate for a wetland will require the following information:

1. Documentation of the final design specifications used to establish the wetland, including any conditions in approvals under EPEA or the *Water Act* or the *Public Lands Act.*

2. Documentation of physical, chemical and biological characteristics of the reclaimed wetland, including summaries of trends over time (see Table 5.2 for a list of potential monitoring parameters for wetlands) and comparison with the draft interim reclamation criteria.

3. Documentation of traditional land use features of the reclaimed wetland.

6.5 Draft Interim Reclamation Criteria

The fundamental principle of reclamation certification is the comparison of post-disturbance landscape, soil and vegetation conditions with original or representative site conditions (e.g., off-site reference areas). In the case of wetlands on the reclaimed landscape, specific criteria have not yet been developed; however, the following draft interim reclamation criteria provide general guidance on the desired characteristics of the reclaimed landscape in relation to wetlands. Government, industry and the public will continue to work toward the further development of criteria for wetlands.

The creation of wetlands on reclaimed landscapes must recognize that a period of time will be required to establish them. The establishment period is expected to be in the order of 10 to 15 years. At that point, the system should be set on a path of ecological succession and development and be "free to evolve.". Wetland systems, including watercourses, should not require long-term maintenance and management.

The following guidelines should be addressed in reclamation planning and certification for wetlands.

Landscape

- The wetland and its associated landscape must be geotechnically stable and consistent with and integrated into the surrounding undisturbed area or adjacent mine areas (i.e., a "seamless" landscape).

- Wetlands on the reclaimed landscape should be comparable to similar wetland types in the surrounding area (e.g., a reclaimed marsh should be similar to off-site marshes in the area). It is recognized that some reclaimed wetlands may not be directly comparable to similar wetlands in the area (e.g., wetlands with elevated salinity from CT seepages). In these cases, appropriate assessment and measurement endpoints will need to be established.

- The landscape surrounding a wetland should be sloped, stabilized and vegetated to minimize erosion and sediment inputs to the wetland. In general, a 3:1 or 4:1 slope will be the maximum permitted.

- Surface drainage must be integrated into the surrounding watershed.

- Watercourses must be structurally similar to native watercourses and stable. They should erode at rates similar to natural watercourses.

- Surface water quality must meet Alberta water quality objectives as outlined in the *Alberta Ambient Surface Water Quality Interim Guidelines (1993)* as amended from time to time. Since these guidelines do not address all water quality parameters of interest, other guidelines such as the *Canadian Water Quality Guidelines* or the *USEPA Water Quality Criteria* will need to be employed. In the event that some parameters are naturally above the objectives in regional waterbodies, documentation will be needed to support a site specific objective.

- Surface waters in wetlands should not exhibit increased chronic or sublethal toxicity that can be associated with process-affected waters in the reclaimed landscape or chronic or sublethal toxicity that is greater than natural reference wetlands. Reclamation certification will recognize that seepage waters, when first released to surface drainage systems, may show evidence of acute or chronic toxicity as measured by aquatic toxicity tests. Onsite receiving water systems may exhibit a gradation in water quality as natural processes take over and mitigate contaminants that may be present. Although there may be some level of toxicity as measured by standard tests, field research has indicated that drainage and wetland systems will be biologically active and inhabited by a sustainable community of organisms. This community should be ecologically viable but may not be fully representative of undisturbed habitats.

- Watercourse vegetation should be similar to that of local natural watercourses and perform similar riparian functions.

- The wetland should provide equivalent capability for wildlife. Target wildlife species should reflect those of the pre-disturbance landscape. Wildlife habitat must consider the various needs of wildlife including travel corridors, visual cover, thermal cover, distance to water, etc. Habitat suitability indices (HSI) and inventories of wildlife use of reclaimed wetlands should be used to demonstrate the return of wildlife capability.

Soils

- Soils should be present in reclaimed wetlands to support ecological functions, vegetation establishment and the intended end land use.
- Soils do not need to be placed in stream channel bottoms and deeper water areas that are not intended to support rooted aquatic vegetation.

Vegetation

- Vegetation must be established in reclaimed wetlands to support the intended land capability and end land use.
- Riparian areas should be revegetated to deciduous cover with a heavy willow/alder component to provide a heavy rooting mat and wildlife habitat, including understory development.
- Native species are preferred for reclamation purposes. Invasive non-native species should not be present in the reclaimed wetland.
- Vegetation must be self-sustaining.
- Wetland reclamation should incorporate traditional use vegetation and activities in the reclaimed landscape. This will have to be developed in consultation with traditional land users. Wildlife, forests and vegetation species important to traditional land users should be addressed.

Other

- Biological and ecological aspects of reclaimed wetlands should be similar or comparable to natural wetlands in terms of features such as biological diversity and community structure (e.g., phytoplankton, zooplankton).
- Plant and animal communities associated with reclaimed wetlands should provide for traditional uses comparable to the pre-disturbance landscape.

7. RECOMMENDATIONS AND PRIORITIES FOR RESEARCH

This guideline represents a preliminary approach to the establishment of wetlands on reclaimed oil sands landscapes. As previously noted there is a degree of uncertainty associated with a number of factors:

1. the hydrology of reclaimed wetlands including soil permeability and the catchment area needed to sustain wetlands on various landforms;
2. the rate of discharge and water quality of seepage waters from the main reclaimed landforms (i.e., CT deposits, overburden waste areas, sand disposal areas);
3. the ecological effects of seepage waters on the wetlands established in the reclaimed landscape;
4. the rate of sediment deposition (i.e., infilling) related to the lifespan required for the treatment of process-affected water or the provision of habitat;
5. the need for further field-scale demonstrations of reclaimed wetlands to provide information on the physical, chemical and biological performance that can be expected at a full-scale operation.

Table 7.1 presents the findings and recommendations of the Wetlands Working Group. It summarizes both general and specific research issues for future work. Priorities are established in terms of short-term (1 to 2 years), medium-term (2 to 5 years) and long-term (> 5 years) for the following issues:

General Issues	Specific Research Issues
1. Pilot-scale demonstration of treatment wetlands	1. Bioaccumulation
2. Pilot-scale demonstration of habitat wetlands	2. CT characteristics
3. Wetlands Working Group	3. CT landforms
4. Water discharge policy	4. Salinity impacts on vegetation
5. Reclamation certification	5. Salinity impacts on waterfowl
6. Wetland management	6. Naphthenic acids
7. Technology transfer	7. Air emissions
	8. Biogenic gases
	9. Wetland reclamation modeling
	10. Vegetation
	11. Wetlands sustainability
	12. Littoral zones
	13. Wetland soils
	14. Peatlands
	15. Riparian reclamation
	16. Traditional use of wetlands

The Wetlands Working Group further evaluated the general priorities in Table 7.1 by using a ranking process to determine the relative priority of various research areas. Appendix J provides the details of the process used. The ranking considered the degree of concern and the degree of knowledge on a particular issue. Areas with the highest priority were those characterized by high concern and low level of knowledge (i.e., a high need for greater knowledge).

Issues associated with the establishment of wetlands on consolidated or composite tails (CT deposits) were identified as the highest priority for research:

1. Water Chemistry
   - salinity in wetlands on CT deposits
   - water release rates of CT deposits
   - treatment capability of wetlands on CT deposits

2. Biology
   - diversity in wetlands on CT deposits
   - bioaccumulation in wetlands on CT deposits
   - chronic toxicity in wetlands on CT deposits
   - chronic toxicity in wetlands on tailings sands
   - riparian areas on CT deposits
   - connector streams on CT deposits

3. Physical
   - hydrology on CT deposits

4. Traditional Land Use
   - traditional uses of wetlands on CT deposits

Table 7.1 General Issues: Findings and Recommendations of the Wetlands Working Group

Pilot-Scale Demonstration of Treatment Wetlands

FINDINGS

Seepage waters from CT landforms and sand storage dumps will likely be acutely toxic to fish (Bishay and Nix 1996). A study of impacts on other organisms is ongoing but the size of the existing experimental wetlands limits the ability to apply the findings to full-scale wetlands.

Impacts of process-affected water on ecology are inevitable. Treatment wetlands may exhibit chronic or sublethal toxicity as shown in field tests using fish, amphibians and ducks. Salinity and other constituents, when present at certain levels, are expected to impact biota at the biochemical, physiological and ecosystem level.

Low winter temperatures may need to be compensated by greater retention times to complete treatment.

Alberta Environment (1995a,b) has defined procedures to develop water quality based standards for approved water releases. These procedures address chemical-specific waste load allocations, mixing zone assessments and whole effluent toxicity assessments.

Overall, considerable information has been gathered from laboratory and field studies; however; the information base needs to be enhanced in terms of the performance of water treatment wetlands and the potential effects that may be exhibited.

RECOMMENDATIONS

Establishment of Pilot-Scale Demonstration Treatment Wetlands on all Types of Reclamation Landforms and Process-Affected Waters

Priority = Short-term (1 to 2 years)

1. Construct scaled-up water treatment wetlands on the three major reclamation landforms (i.e., CT deposits, overburden dumps, sand storage areas) and monitor their performance and development.
2. Assess the design of treatment wetlands to balance the need for dilution and short retention times to minimize any on-site impacts of salinity (i.e., dilute this water and route it into receiving streams) versus the need for long retention times in wetlands to provide treatment for organic compounds (e.g., naphthenic acid) and metals.
3. Evaluate treatment capability over winter since this is a key information requirement on the performance of treatment wetlands.
4. Confirm the retention time required for removal of chronic toxicity (est. 1 year) since Suncor's research extrapolated data outside the range of that tested (i.e., retention times could not be extended to 1 year in small trenches).
5. Evaluate issues associated with increased size or scale-up (e.g., flow patterns, treatment effectiveness).
6. Establish systems that have separate test cells to assess alternative strategies (e.g., additions of phosphorus, impact of varying levels of transplanting, thickness of soil/sediment amendments).
7. Include aboriginal peoples in the wetland research program, in particular with regard to traditional uses (e.g., traditional plants) and the testing of traditional use plant species.
8. Develop appropriate guidelines needed to assess acceptable ecological characteristics in water treatment wetlands.

Pilot-Scale Demonstration Habitat Wetlands

FINDINGS

Existing research has been conducted in wetlands that do not exactly reflect the nature of those expected to be created after reclamation (e.g., water flow rates, substrate type, size).

RECOMMENDATIONS

Establishment of Pilot-Scale Demonstration Habitat Wetlands Downstream from All Types of Treatment Wetlands

Priority = Short-Term (1 to 2 years)

9. Construct experimental "demonstration" habitat wetlands downstream from each treatment wetland to assess their ecological acceptability.

10. Integrate pilot-scale wetlands into CT deposits that are being constructed at both Suncor and Syncrude to test issues related to ecological acceptability and sustainability.

11. Monitor ecological succession over time using a broad suite of biological parameters. Establish trends in colonization, invasion rates, species composition, species diversity, abundance, and community structure. This information will allow trends to be established that can be used to evaluate the performance of the wetland over time.

12. Conduct focussed research on these three sites that includes population studies for key aquatic plants and animals.

13. Establish a pond or stream downstream of these habitat wetlands to test any impacts of wetlands discharges on receiving water bodies.

14. Include aboriginal peoples in the wetland research program, in particular with regard to traditional uses, including the selection and testing of traditional use species and the development of criteria to measure successful establishment.

Wetlands Working Group

FINDINGS

The present group consists of representatives from oil sands operators, regulators, academia, consultants and aboriginal peoples.

This guideline provides information for use by reclamation planners and closure teams.

Verification and updating of the approach to wetlands design and certification will be needed as experience and additional knowledge are obtained.

RECOMMENDATIONS

Continuation of the Wetlands Working Group

Priority = Medium-Term (2 to 5 years)

15. Modify and expand the guideline for wetland design to reflect changes in mine reclamation technologies and closure planning designs.
16. Assess implications and possible mitigation strategies regarding the performance of wetlands created on reclaimed landscapes.
17. Incorporate reclamation experience gained by operators, regulators and the public.
18. Add scientific advances in wetlands construction techniques.
19. Provide more input from aboriginal peoples regarding their needs. Provide a linkage with both the planning and implementation of the pilot-scale wetlands work.
20. Evaluate performance criteria and design considerations with respect to the preliminary recommendations in the guideline.

Water Discharge Policy

FINDINGS

For the most part, existing and planned oil sands operations function under a "zero discharge" policy whereby process-affected waters are not released. However, these waters will be released from the reclaimed landscape after mine closure (i.e., as reclamation release waters).

Landscape design during reclamation (e.g., CT technology) and water recycle options during operations (e.g., water balance) will both affect water release characteristics and wetland distribution and numbers on the final reclaimed landscape.

Increased water recycling during operations will decrease the demand for withdrawals from the Athabasca River but it also increases the salt content of CT seepage water. There may be a conflict between decreased water recycling during operations versus increased salt concentrations after mine closure (which also may have adverse ecological impacts).

Elevated levels of salts (or other chemicals) in water released from sand storage and CT landforms will impact on the number and distribution of treatment wetlands as well as the ecology of habitat wetlands and receiving water bodies such as rivers and lakes. The precise salinity of these waters may be difficult to predict; therefore, the ecological acceptability of treatment wetlands has a degree of uncertainty.

It may be more appropriate to approve operational discharges (which can be monitored and controlled) versus their long-term storage and eventual release after mine closure (when control may be difficult and treatment options limited).

RECOMMENDATIONS

Examination of the zero discharge policy compared with the treatment and discharge of process-affected waters during operations

Priority = Medium-Term (2 to 5 years)

21. Review and evaluate the environmental implications of water recycle and reclamation options in terms of the treatment capability, ecological acceptability, cost and sustainability of treatment wetlands or other treatment methodologies.

22. Explore with stakeholders the concept of discharging water through treatment systems (including wetlands) during plant operations since this might substantially reduce the volume of reclamation release waters discharged after mine closure when treatment options may be limited (i.e., wetlands may be the only practical method after mine closure).

23. Explore a treatment system which combines the advantages of engineering technologies (rapid removal rates) with passive wetlands (low costs), if operational discharges are accepted by all stakeholders.

Reclamation Certification

FINDINGS

Reclamation is deemed complete and successful with the granting of a reclamation certificate.

Many issues related to the certification of wetlands have yet to be resolved and the science of wetlands restoration lacks adequate standards for success due to: 1) limited understanding of basic functions, 2) short time frames, and 3) an inability to recognize the importance of nature rather than design (Mitsch and Wilson 1996).

Certification criteria will need to be developed through an iterative process. Criteria should be science-based, practical and achievable.

If this process is initiated now on an experimental basis, a developing consensus could be formed among all stakeholders with less chance of retroactive guidelines being imposed on industry in the future.

Biological communities will colonize new habitats over time. The structure and function of created wetlands established on the reclaimed landscape will change as species invade the new habitat. Water treatment wetlands will show effects from the waters that are being treated. As the flows or characteristics of these waters attenuate over time, the biological communities should correspondingly reflect this change.

Mitsch and Wilson (1996) recommend a 15 to 20 year period before success can be fully evaluated.

RECOMMENDATIONS

Development of Certification Criteria

Priority = Medium-Term (2 to 5 years)

24. Develop practical and achievable design criteria to meet intended wetland functions and uses.

25. Develop preliminary certification procedures (e.g., process, guidelines) based on the physical, chemical and biological characteristics of a reclaimed wetlands.

26. Assess one or more experimental wetland types through a preliminary “unofficial” certification process to provide a framework for establishing the acceptability of the proposed reclamation design criteria for created wetlands. Clarify the process and establish precedents for certification.

27. Incorporate input from all stakeholders with respect to certification and certification criteria.

28. Develop and confirm performance indicators to provide evidence that a reclaimed wetlands area is evolving and will mature into sustainable and ecologically acceptable created wetlands.

Wetland Management

FINDINGS

After a wetland is established on the reclaimed landscape, there will be a need to address various management issues. Some level of management will likely be needed in order to achieve the intended functions and performance expectations of the wetland. This could include such measures as water level control, fertlization, erosion control, etc.

RECOMMENDATIONS

Development of wetland management plans

Priority = Medium-Term (2 to 5 years)

29. Identify operational and management issues for flood control and water treatment wetlands. Depending on objectives, these issues could include vegetation control, wildlife management, water quality management, licensing limits, hydrological controls, and integrity of structures. To deal with these issues, it will be necessary to define: 1) operating goals, 2) basis for problem identification, 3) causative factors, 4) appropriate management strategies, 5) lead time required, and 6) the methods to evaluate the effectiveness of the corrective action.

Technology Transfer

FINDINGS

Considerable effort has been made through laboratory and field research to understand the feasibility of creating waterbodies (e.g., Syncrude's small test pits and demonstration pond) and using constructed wetlands to treat oil sands water releases (e.g., Suncor's experimental water treatment channels).

Over the next few years it is expected that a number of wetlands will be planned and established on reclaimed landscape and subsequently monitored.

In addition, there exists an ever-expanding base of technical literature, including published research articles, reports by oil sands operators, and textbooks.

RECOMMENDATION

Development of communication and information-sharing processes

Priority = Short-Term (1 to 2 years)

30. Establish an effective means of synthesizing and disseminating information on wetlands establishment, including summary reports, workshops, field tours and presentations at conferences.

Table 7.2: Specific Research Issues: Findings and Recommendations of the Wetlands Working Group

Bioaccumulation

FINDINGS

Process-affected release water or water from dewatered peatlands may contain levels of metals that would exhibit toxic effects (Shotyle 1986; Westling 1991). Even if relatively low, levels may be biomagnified to produce effects or metals may be accumulated into sediments to produce long-term impacts.

Bioavailability is expected to be low; however, metals may be mobilized through microbial action. For example, mercury may increase in the aquatic ecosystem due to anaerobic processes in the sediment (Winfrey and Rudd 1990) or due to enhanced oxidation of peatlands (Stober et al. 1995).

RECOMMENDATIONS

Metal Concentrations in Plant and Animal Tissue with Reference Wetlands

Priority = Medium-Term (2 to 5 years)

31. Evaluate the nature and extent of metal levels in pilot-scale systems (treatment wetlands and habit wetlands).

32. Monitor metal levels in water, sediment and biological tissue.

33. Compare metal levels in plant and animal tissues in reclaimed wetlands to levels in natural or reference wetlands.

34. Conduct field research to assess the capability of biogeochemical processes to demethylate mercury in treatment and habitat wetlands.

CT characteristics

FINDINGS

CT technology represents a major advance in the reclamation of land disturbed by oil sands mining; however, there are issues that require further understanding; however, CT release water exhibits variability depending on the operator's CT process and the ore source. Operators are continuing to evaluate their individual CT waters.

RECOMMENDATIONS

Characterization CT release waters

Priority = Medium-Term (2 to 5 years)

35. Conduct further studies on the physical, chemical and biological aspects of CT technology, in particular: 1) CT chemistry, 2) CT release rates, and 3) transport and fate of constituents
36. Fate processes should consider all of the following: bacterial conversion, sedimentation, natural decay, adsorption, volatilization, and chemical reactions.
37. Input data into reclamation landscape models.

CT Landforms

FINDINGS

In the last few years, pilot-scale tests of CT technology have been conducted. However, a large-scale CT landform has not yet been created since this technology for tailings disposal is relatively new.

Issues such as subsidence (extent and variability) as well as the characterization and rate of seepage of CT release water will have important implications for the creation of wetlands on CT landscapes. At present, these implications are not fully understood.

Maintenance of these wetlands may be required for an unknown period until flows of CT release water are diminished. Concentrations of salts, naphthenic acids, ammonia or other compounds will vary over time but should diminish in the long-term.

RECOMMENDATIONS

Stability and Characteristics of CT Landforms

Priority = Long-Term (> 5 years)

38. Monitor subsidence and water release rates (in terms of wetlands sustainability) on CT deposits currently being constructed.
39. Monitor salinity and all other constituents of concern in pilot or field-scale experiments.

Salinity Impacts on Vegetation

FINDINGS

The release of reclamation drainage water from CT landforms will result in the discharge of water with elevated levels of salinity, perhaps from both surface and groundwater sources. There may be other sources of salinity due to sodic materials in overburden.

Saline discharges will impact aquatic ecosystems exposed to this water including riparian areas. Elevated salinity could effect changes in species composition and abundance, growth, population dynamics, community structure and ecosystem structure and function.

RECOMMENDATIONS

Salinity Levels and Saline-Tolerant Plants

Priority = Short -Term (1 to 2 years)

40. Use pilot-scale wetlands to define the potential elevation of salinity in reclaimed wetlands.
41. Establish a list of saline tolerant plants native to the Central Mixedwood Region of the Boreal Forest as an aid to revegetation plans for wetlands that are predicted to have high salinity.
42. Access salinity and vegetation data by reviewing past studies (e.g., EIA's) and scientific literature.
43. Maintain/expand ongoing research, especially on effects of salinity on plant and animal diversity.
44. Establish the salinity tolerance of traditional plants used by aboriginal peoples.

Salinity Impacts on Waterfowl

FINDINGS

Recent evidence using on-site experiments suggests that duck growth may be inhibited by process-affected waters (Bendell-Young et al. 1998). High sulphate water may cause greater stress on birds than equivalent concentrations of sodium chloride (Swanson et al. 1984)

RECOMMENDATION

Threshold Values for Impacts of Salinity on Waterfowl (and other wildlife)

Priority = Short -Term (1 to 2 years)

45. Conduct focussed laboratory and field research to define potential impacts of sulphate-dominated salinity on wildlife, especially waterfowl.

Naphthenic Acids

FINDINGS

These compounds occur naturally in the oil sands region but are elevated as a result of the extraction of bitumen from oil sands.

They represent a large number of individual compounds within a group of heterocyclic carboxylic acids.

They are typically found in process-affected water, are relatively slow to biodegrade, and exhibit acute and chronic toxic to a variety of aquatic organisms. Notwithstanding the fact that naphthenic acids are not aromatic structures, they are heterocycles and hence may influence sulfur metabolism (Catallo and Gambrell 1995).

Currently, there is not a well-established correlation between their concentration and the degree of toxicity, primarily due to their complex chemical structure and analytical limitations which make it difficult to isolate individual acids.

RECOMMENDATION

Chemical Characterization and Toxicity of Naphthenic Acids

Priority = Short-Term (1 to 2 years)

46. Conduct further research to assess the potential for acute or chronic toxicity of naphthenic acids, and attenuation of this toxicity, to both aquatic and terrestrial plants and animals. Include research on how to increase or enhance the rate of attenuation of toxicity.

47. Summarize results of recent research programs (e.g., perch study, fathead minnow study, immune response study, plankton study).

48. Evaluate existing data to establish NOEL's (No Observed Effects Levels).

49. Review existing data and recommendations of the *Naphthenic Acids Background Information Discussion Report* (CEATAG 1998).

50. Conduct further toxicological and chemical characterization work.

51. Conduct further research into quantitative analytical methods for naphthenic acids.

Air Emissions

FINDINGS

Progressive reclamation requires the establishment of viable wetlands during the operational phase of the mine. However, air emissions from the plant and adjacent mines may have the potential to affect wetlands established on the reclaimed landscape.

RECOMMENDATIONS

Impacts of Air Emissions on Wetlands

Priority = Long-Term (> 5 years)

52. Consider studies on the effects of air emissions on vegetation in wetlands near the plant site.

Biogenic Gases

FINDINGS

Greenhouse gases include gases such as methane and carbon dioxide that contribute to global warming.

Wetlands release greenhouse gases. Bogs/fens produce much less methane than do marshes in this region (Vitt et al. 1990).

Methane and hydrogen sulphide (as well as other gases) may diffuse upwards through the substrate from underlying CT landforms as a result of microbial activity in this water-saturated zone (i.e., perhaps similar to existing tailings ponds which now release large amounts of these gases).

Creating new types of wetlands will result in changes in gas ratios or mass balances since this occurs with even small functional alterations of wetlands systems (SETAC 1988).

RECOMMENDATIONS

Field Studies on Gas Production and Assimilation Rates

Priority = Long-Term (> 5 years)

53. Conduct research on aspects of sulphur metabolism in wetlands (some work is ongoing at the University of Alberta) to assess the potential for releases of hydrogen sulphide and methane and any positive benefits (e.g., precipitation of metals) or negative impacts (i.e., greenhouse gases, toxicity).

54. Continue field monitoring of gas production from reference and created wetlands to assess the amounts of greenhouse gas contributions from pre-development and post-development landscapes.

55. Explore the capability of methane oxidizing microbes in wetlands water (or the upper layers of soils) to assess possible measures to reduce overall emissions (if harmful levels are being released).

56. Assess the benefits of utilizing gas monitoring as an analysis of wetlands health.

Wetland Reclamation Modeling

FINDINGS

Effective planning of wetlands requires the integration of physical, chemical and biological processes at a landscape level. The sources, fates and ecological effects of potential contaminants need to be soundly understood. Syncrude and Suncor have previously advanced the develop-ment of a Reclamation Landscape Model as a tool for impact assessment and reclamation planning. The model links a dry landscape module, wet landscape module and wetlands module.

RECOMMENDATION

Further Development of the Reclamation Landscape Model

Priority = Long-Term (> 5 years)

57. Further develop the landscape reclamation model as a key aid in the planning and design of wetlands.

Vegetation

FINDINGS

Wetland vegetation may need to be planted as quick start for wetland development.

Vegetation used by aboriginal peoples may need to be planted in created wetlands

Past research indicates that natural colonization can be an effective means to establish wetlands vegetation or to infill planted vegetation. There are cases where the planted vegetation has been replaced by other species within several years.

RECOMMENDATION

Development of Revegetation Techniques

Priority = Medium-Term (2 to 5 years)

58. Undertake a field-scale revegetation trial with consideration of factors such as wetlands size, transplant type (e.g., individual plants, ecosystem swatch), level of effort (e.g., distribution and density), time for establishment and proximity and connectivity with natural wetlands.

59. Include aboriginal peoples in the design, establishment, monitoring and assessment in research on important traditional species in each wetland type.

60. Conduct field tests with species considered important to aboriginal users.

Wetland Sustainability

FINDINGS

Hydrology is the driving factor regulating wetland functions and characteristics. Therefore, sustainability generally refers to the hydrological regime and the ability to retain water over most of the year, thereby maintaining the wetland.

A study of agricultural lands in Alberta shows that the ratio of catchment area:wetland varies between 100:1 and 4:1 (Appendix C). A ratio of uplands:wetlands of 8:1 provides an adequate watershed to sustain wetlands near Saskatoon (Dr. Barbour, pers. comm.)

As noted in the report prepared by the Oil Sands Water Release Technical Working Group, on-site sustainability should lead to the protection of biological integrity (i.e., the ability of on-site systems to support and maintain a community of organisms that is balanced, integrated, adaptive and comparable to natural systems in terms of composition, diversity, functional processes and ecological processes).

Currently, there is not a clear definition of what constitutes a sustainable system.

RECOMMENDATIONS

Investigation of Sustainability Factors and Wetland Assessment Techniques

Priority = Long-Term (> 5 years)

61. Conduct further hydrological research to assess the uplands:wetlands ratio needed to sustain wetlands within the differing reclamation landscapes, especially for CT landforms. Address sustainability on watersheds less than 100 km^2 in size which may be typical on reclaimed landscapes.

62. Research sediment yield rates from varying landscapes.

63. Develop assessment and measurement endpoints for reclaimed wetlands to address on-site ecosystem health and sustainability.

64. Establish definitions/guidelines based on “reference sites” or “benchmark sites.” Use a number of attributes at the species, population, community and ecosystem level, as well as traditional use species.

65. Establish health and ecological risk assessment techniques to evaluate potential risk to on-site users and wildlife communities in the reclaimed landscape.

66. Continue to build on the ecological and ecotoxicological studies that have been conducted to date.

67. Examine groundwater contributions to surface water in undisturbed areas.

Littoral Zones

FINDINGS

Littoral zones around end pit lakes will be integral to the lake. These zones may be exposed to chemical constituents that arise from drainage inputs or from destratification within the lake.

RECOMMENDATION

Treatment Capability of Littoral Zones

Priority = Long-Term (> 5 years)

68. Review the capacity of littoral areas in end pit lakes to degrade or remove constituents of concern in drainage inputs or from destratification of the lake.

69. Assess the impact on littoral zones of periodic elevated levels of chemical constituents that could be released from an end pit lake.

Wetland Soils

FINDINGS

Soil/sediment is an integral part of a reclaimed landscape, including wetlands. Soils provide the rooting medium for aquatic macrophytes as well as the medium for microbial activity. At present there is incomplete understanding of the biological response of wetlands to various soil treatments.

RECOMMENDATION

Wetland Soils Research

Priority = Long-Term (> 5 years)

70. Conduct experiments on the type (e.g., peat, mineral, peat/mineral), depth, quality and distribution of soil in relation to establishing functioning biological communities, in particular microbial communities and macrophytes.

Peatlands

FINDINGS

Currently, the feasibility of establishing peatlands on reclaimed landscapes is low due to the expected changes in water chemistry (e.g., salinity, pH) and the slow rate of peat accumulation.

"Peatland restoration … may represent a feasible option for reclamation – the ability of peatlands to sequester carbon is a global value and should be considered as a desirable option by industries currently responsible for CO_2 emissions to the atmosphere." (M. Turetsky in prep.).

RECOMMENDATIONS

Potential for Reclamation of Disturbed Land to Peatlands

Priority = Long-Term (> 5 years)

71. Review the assumption that peatlands cannot be created using, in part, information from existing peatland operators. Create a plan for further discussion on methods to enhance or create the precursor conditions for future peatland establishment.

Traditional Uses of Wetlands

FINDINGS

Aboriginal peoples use wetlands for subsistence hunting, trapping, and food and medicinal plant collection , as well as for spiritual and cultural purposes. The desire and need to maintain their culture is closely linked to the ability to practice traditional activities even if they are not living a completely traditional life style. For traditional uses to be returned, wetland research will need to confirm that the reclaimed wetlands will produce plants and animals that have levels of contaminants such that their use for consumption by aboriginal peoples will be acceptable.

Consultation with local aboriginal communities will maximize opportunities for reclaimed wetlands to provide traditional uses. Consultation needs to take place in all stages of wetland establishment.

RECOMMENDATION

Potential and Methods for Establishment of Traditional Uses in Reclaimed Wetlands

Priority = Short Term (1 to 2 years)

72. Include aboriginal peoples in the design, establishment, monitoring and assessment on research programs on important traditional species in each wetland type.

73. Conduct field tests with species considered important to aboriginal users.

74. Investigate potential levels of contaminants in species consumed by aboriginal peoples.

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9. GLOSSARY OF TERMS

Abundance: The number of organisms per unit area or volume

Acute: With reference to toxicity, having a sudden onset, lasting a short time (usually within hours or days for fish). With reference to a stimulus, severe enough to rapidly induce a response. It can be used to define either the exposure (time) or the response to an exposure (effect). The duration of an acute aquatic toxicity test is generally hours to a few days and mortality is the response measured.

Acute Toxicity: Toxicity that occurs rapidly as a result of short-term exposure to a substance. The exposure period is short (generally hours or days) in relation to the organism's life cycle. Mortality (death) is the response measured.

Adaptive Management A management approach that involves the monitoring and evaluation of wetland performance followed by any necessary actions to achieve the intended performance objectives. Adaptive management also allows information to be fed back into the planning and design process so that future wetlands will meet wetland objectives.

Aeration Any process where a substance becomes permeated with air or another gas. The term is usually applied to aqueous liquids being brought into intimate contact with air by spraying, bubbling or agitating the liquid.

Aesthetic Dealing with those aspects of water that are perceivable to the senses.

Algae A group of aquatic plants, variously one-celled, colonial or filamentous, containing chlorophyll and/or other pigments and having no vascular system.

Anaerobic Living or active in the absence of oxygen.

Aquatic Growing, living in or frequenting water; occurring or situated in or on water.

Aquatic Ecosystem The biological community and the non-living environment functioning together as a system in waterbodies. Aquatic habitat for interrelated and interacting communities and populations of plants and animals.

Aquatic Ecotoxicology The integrated study of the fate and effect of toxic substances in aquatic ecosystems, including their biological communities.

Aquatic Toxicology The study of the effect of toxic substances on a target freshwater, estuarine or marine species.

Bioaccumulation A general term, meaning that an organism has within its body a higher concentration of a substance than is found in its environment. Includes uptake of substances from water (= bioconcentration) and from food. This phenomenon is not necessarily harmful. For example, freshwater fish must bioaccumulate common salt if they are to live because the water in which they swim dissolves the salts out of their bodies. Many toxicants, such as arsenic, can be excreted by aquatic organisms, and are not included among the bioaccumulative substances

Bioassay The use of an organism or part of an organism as a method for measuring or assessing the presence or biological effects of one or more substances under defined conditions. A bioassay test is used to measure a degree of response (e.g., growth or death) produced by exposure to physical, chemical or biological variable. A bioassay is also referred to as a toxicity test.

Biodegradable Able to be decomposed, as a result of the action of microorganisms such as bacteria. Materials are considered to be biodegradable if they decompose relatively quickly.

Biodiversity The variety of living components of ecosystems. Biodiversity can be assessed from a number of perspectives depending on context and scale. It is most often expressed in terms of species diversity but can be assessed on the basis of genetic diversity or landscape diversity (e.g., variety of vegetation types across the landscape). Biodiversity can also incorporate structural and functional elements.

Biological Monitoring Systematic determination of the effects on aquatic life, including accumulation of pollutants in tissue, in receiving waters as a result of the discharge of pollutants: (a) by techniques and procedures, including sampling of organisms representative of appropriate levels of the food chain, appropriate to the volume and the physical, chemical, and biological characteristics of the effluent, and (b) at appropriate frequencies and locations.

The direct measurement of changes in the biological status of an environment or effluent based on the use of living organisms as "sensors" or "indicators"; may involve bioassay testing and/or continued evaluations of the number and distribution of individuals or species in an environment.

Biological Treatment A wastewater treatment process that utilizes heavy growth of microorganisms for the purpose of oxidizing, absorbing, and adsorbing wastewater impurities, both organic and inorganic.

Biomass The weight all living material in a unit are or volume at a given instant in time. It can be expressed at different biological levels (e.g., population, community).

Carbon (C) A non- metallic element found native (as diamonds and graphite) or as a constitute of coal, petroleum, limestone and other carbonates, and all organic compounds.

Cation A positively charged ion.

Cation-Exchange Capacity The total quantity of cations which a soil can adsorb by cation exchange, usually expressed as milliequivalents per 100 grams. Measured values of cation-exchange capacity depend somewhat on the method used for the determination.

Chronic Involving a stimulus that is lingering or continues for a long time; often signifies periods from several weeks to years, depending on the reproductive life cycle of the aquatic species. Can be used to define either the exposure or the response to an exposure (effect). Chronic exposure typically induces a biological response of relatively slow progress and long continuance. A chronic aquatic toxicity test is used to study the effects of continuous, long-term exposure at low concentrations of a chemical or other potentially toxic material on aquatic organisms.

Chronic Effects Adverse effects on growth, reproduction, etc. of an organism due to long term exposure to sublethal contaminant concentrations.

Chronic Test A bioassay (toxicity test) that examines subtle effects (e.g., growth rates, larval development) rather than mortality.

Chronic Toxicity Toxicity marked by a long duration, that produces an adverse effect on organisms. The end result of chronic toxicity can be death although the usual effects are sublethal (e.g., inhibiting reproduction or growth). These effects are reflected by changes in the productivity and population structure of the community. Often signifies effects occurring over periods of at least one tenth of the life span of the organism.

Community An assemblage of organisms characterized by a distinctive combination of species occupying a common environment and interacting with one another. Group of populations of plants and animals in a given ecological unit; used in the broad sense to include groups of various sizes and degrees of integration.

Conductivity A measure of the resistance of a solution to electrical flow; conductivity increases with increasing ion content.

A numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the concentrations of ions in solution, their valence and mobility, and on the solution's temperature. Conductivity is normally reported in the SI unit of millisiemens/metre, or as micromhos/cm (a mS/m = 10 umhos/cm).

Consolidated/Composite Tailings (CT) Consolidated (Suncor) or Composite (Syncrude) Tailings (CT) is formed by injecting mature fine tailings from the tailings ponds into the regular tailings sand stream, with a flocculent such as gypsum. This mixture forms a non-segregating soil mixture that will result in a trafficable surface in the reclaimed landscape.

Contaminant A substance that is not naturally present in the environment or is present in unnatural concentrations or amounts which can, in sufficient concentrations, adversely alter an environment.

Coversoil In the oil sands region, coversoil refers to salvaged surface soils that are replaced on land disturbed by oil sands operations. Coversoil includes any topsoil or other soil material salvaged for use in surface reclamation that is rated as good or fair in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (Alberta Agriculture, 1987).

Criteria (Water Quality) An estimate of the concentration of a chemical or other constituent in water which, if not exceeded, will protect an organism, a community of organisms, or a prescribed water use or quality with an adequate degree of safety.

Cumulative Brought about, or increased in strength, by successive additions at different times or in different ways.

Detritus Non-living particles of disintegrating biological material (inorganic and dead and decaying organic material) that can be suspended in the water column or deposited on the bottom of lakes, streams, oceans, etc.

Dissolved Oxygen (DO) Oxygen which is present (dissolved) in water and therefore available for fish and other aquatic animals to use. If the amount of dissolved oxygen in the water is too low, aquatic animals suffer from suffocating. Wastewaters discharged into the environment often contain oxygen demanding substances (e.g., organic compounds) which, as they are decomposed by naturally occurring bacteria, can consume dissolved oxygen. Dissolved oxygen is normally measured in mg/L (equivalent to parts per million) and widely used as a criterion of receiving water quality.

Ecosystem A system of living organisms interacting with each other and their non-living environment, linked together by energy flows and material cycling.

Endpoint The variable(s) (i.e., time, reaction to the organisms, etc.) that indicate(s) the termination of a test, and also means the measurement(s) or value(s) derived that characterizes the results of the test (e.g. EC50, LC50).

Environment All biotic and abiotic factors that actually affect an individual organism at any point in its life cycle.

Environmental Impact Assessment A broad field that includes all activities that attempt to analyze and evaluate the effects of human action on natural and anthropogenic environments.

Erosion (water) The wearing away and transportation of soils, rocks and dissolved minerals from the land surface, shorelines and river bottoms by rainfall, running water, wave or current actions.

Evapotranspiration A collective term for the processes of evaporation and plant transpiration by which water is returned to the atmosphere from the land.

Flow A volume of water passing through a reach of the river, per unit time.

Flushing The rate at which water passes through a waterbody (a mechanism that removes dissolved/suspended nutrients from the system).

Food Web A community of organisms which are connected by dependence upon one another for food.

Food chain The process by which organisms in higher trophic levels gain energy by consuming organisms at lower trophic levels; the dependence for food of organisms upon others in a series beginning with plants and ending with the largest carnivores.

Freshwater Habitat In the guideline document, freshwater habitats are considered to be lakes, reservoirs, ponds, rivers and streams. The guideline could be adapted to monitor other freshwater habitats, such as wetlands, marshes, fens, etc.; however, specific characteristics of these habitats (and sampling methods) have not been considered here.

Graminoid Wetlands Wetlands dominated by grass or sedge species.

Groundwater Underground water supplies, also called aquifers.

Habitat The specific area or environment in which a particular type of plant or animal lives. An organism's habitat provides all of the basic requirements for the maintenance of life. Typical coastal habitats include beaches, marshes, rocky shores, bottom sediments, mudflats, and the water itself.

Inorganic Not pertaining to or derived from plant or animal origins (organisms); a chemical of mineral origin which does not contain (with few exceptions) carbon or compounds of carbon.

Invertebrates Animals lacking a dorsal column of vertebrae or a notochord.

Land Use The way land is developed and used in terms of the types of activities allowed (agriculture, residences, industries, etc.) and the size of buildings and structures permitted.

Littoral Productive shallow-water zone of lakes, rivers or seas with light penetration to the bottom - often occupied by rooted aquatic plants.

Macrophyte A member of the macroscopic plant life (i.e., larger than algae) especially of a body of water; refers to the macroscopic forms of aquatic vegetation.

Measurement Endpoint An expression of an observed or measured response to a hazard; it is a measurable environmental characteristic that is related to the valued characteristic chosen as the assessment endpoint.

Mercury A heavy metal recognized as a dangerous substance because it bioaccumulates through the food chain and can affect the central nervous system.

Metals Elements such as mercury, lead, nickel, zinc and cadmium that can be of environmental concern. Although many are necessary nutrients, they are sometimes magnified in the food chain, and they can be toxic to life in high concentrations.

Methylation The introduction of methyl (CH_3) groups into organic and inorganic compounds.

Microbes Any organism that can be observed only by the aid of a microscope. These include viruses, bacteria, protozoa, and some algae and fungi.

Mitigation The process of rectifying an impact by repairing, rehabilitating or restoring the affected environment, or the process of compensating for the impact by replacing or providing substitute resources or environments.

Monitoring Measurements taken over space or time for the purpose of characterizing and assessing environmental conditions.

Nitrogen Non-metallic element that plays a major role in biological metabolism.

Nitrogen:Phosphorus Ratio The ratio of the weight of nitrogen to the weight of phosphorus in a medium such as soil or water. Nitrogen and phosphorus are two of the most important nutrients in freshwater systems because inadequate supplies of either nutrient will limit plant (algal) growth and reduce food supplies for the other organisms in the system. Freshwater systems (e.g., lakes, streams), are most often phosphorus limited. Measurement of the relative concentrations of nitrogen and phosphorus in freshwater systems has shown that when the N:P ratio is greater than 14:1, the supply of phosphorus limits the growth of algae. When the N:P ratio is less than 10:1, the supply of nitrogen limits the growth of algae.

Nutrient A chemical that is an essential raw material for the growth and development of organisms.

Nutrient Limiting Refers to the limitation of an organism or population growth or productivity, due to a limited supply of an essential nutrient. For example, if an organism or population is limited by phosphorous then it does not matter how much nitrogen is available; productivity will not increase until there is more of the limiting nutrient phosphorous.

Permeability The capacity of some structures (e.g., a porous rock, soil, or sediment) for allowing water to be transmitted without damage to the structure.

Phosphorus Non-metallic element that plays a major role in biological metabolism. Compared to the other macronutrients required by biota (e.g., carbon and nitrogen), phosphorus is least abundant and is the first element to limit productivity of algae in freshwater aquatic systems. Orthophosphate (PO_4^{3-}) is the only directly utilizable form of soluble inorganic phosphorus.

Plankton Small plants (phytoplankton) and animals (zooplankton) that are suspended in the water and either drift with the currents or swim only short distances.

Primary Productivity The rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producer organisms (chiefly green plants) in the form or organic substances.

Productivity The rate of formation of organic matter averaged over some defined period of time, such as a day or a year. The term productivity has been used extensively in many different ways. Generally, it is related to the realized or actual potential of organisms (or a functional group of organisms or an ecosystem) to produce organic material over a stated time period. Since productivity is a rate, it is important to evaluate the given variable (biomass, growth, volume, organic carbon) over a reasonable time period for the group of concern. Productivity is a measure of the total biological activity of a system, reflecting the total amount of plant/animal biomass produced in a given time period by the system. It includes primary (algal), secondary and tertiary (animal) production.

Reclamation The stabilization, contouring, maintenance, conditioning or reconstruction of the surface of the land with the objective of returning equivalent land capability. This means that the ability of the land to support various land uses after reclamation is similar to the ability that existed before the land was disturbed, but that the individual land uses may not be the same.

Reclaimed Soil Soil created by the selective placement of suitable topsoil and subsoil material on reshaped spoil, tailings or parent geological material.

Recycling The return of processed or used materials, such as fibre, paper, water, and chemicals, back to the original process to make a new product.

Reference Area An area which is undisturbed or unaffected by an activity and therefore can serve as a comparison to assess the state of an area than has been disturbed or affected by an activity.

Refugia A stand of undisturbed natural vegetation retained within a mine development area that serves as a source of native species revegetation.

Riparian — Areas or species associated with river or creek systems or other wetlands. Usually refers to the bank areas of a watercourse of the edge of a waterbody.

Residence Time — Average time spent by a parcel of water in a basin (i.e., wetlands) before being discharged.

Risk Assessment — A set of formal scientific methods for estimating the probabilities and magnitudes of undesired effects resulting from the release of chemicals, other human actions or natural catastrophes.

Saline — An aqueous environment containing dissolved salts.

Sedimentation — The process of accumulating sediment at the bottom of a water body over time from the sinking debris in the water (e.g., from river discharges or from the death of plants and animals living in the water).

Soil Permeability — The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil.

Sublethal — Involving a stimulus/concentration below the level that causes death. Exposure to sublethal concentrations of a material may produce less obvious effects on behaviour, biochemical and/or physiological function, and histology of organisms.

Sulphate (SO_4) — A widely distributed anion in natural waters in concentrations from a few to several thousand mg/L.

Suspended Solids — Organic or inorganic particles that are suspended in and carried by the water. The term includes sand, silt, and clay particles as well as solids in wastewater. Measured as the oven dry weight of the solids, in ppm, after filtration through a standard filter paper. Less than 25 ppm would be considered clean water, while an extremely muddy river might have about 200 ppm of suspended solids.

Treatment — Chemical, biological, or mechanical procedures applied to an industrial or municipal discharge or to other sources of contamination to remove, reduce, or neutralize contaminants.

Trophic Level Functional classification of organisms in a community according to feeding relationships - the first trophic level includes green plants, the second level includes herbivores (plant eaters), etc.

Water Quality Guideline A numerical concentration or narrative statement recommended to support and maintain a designated water use. A guideline is generally derived from the lowest observable effect level (LOEL) obtained from biological tests of chronic toxicity. The LOEL is multiplied by a safety factor to provide for the long-term protection of important aquatic species or other uses.

Water Quality Objective A numerical concentration limit or narrative statement which has been established to support and protect the designated uses of water at a specified site. Site specific conditions determine how an objective would be developed. An objective for a specific area will depend on existing and future water uses and the most sensitive aquatic organisms that are present.

Wetlands Habitats where the influence of surface or groundwater has resulted in development of plant or animal communities adapted to aquatic or intermittently wet conditions. Wetlands include tidal flats, shallow subtidal areas, swamps, marshes, wet meadows, bogs, fens and similar areas.

Wetlands Function The natural processes associated with wetland ecosystems, or what a wetlands does, without respect to any worth or value being assigned to it by society.

Wetlands Types **bog:** a peat-covered area with the water table at or near the peat surface. The surface water and nutrients are derived mainly from precipitation resulting in a very acidic, nutrient-poor environment. Sphagnum moss has the ability to further acidify its environment. Vegetation tolerant of such harsh conditions includes Sphagnum mosses, Labrador tea and black spruce.

fen: a peat-covered area with the water table at or above the peat surface. Fen water is influenced by runoff or groundwater and is relatively nutrient-rich and slightly acidic to alkaline due to contact with mineral soil.

Vegetation can include sedges, mosses, grasses, reeds, willow, black spruce and tamarack.

marsh: areas periodically inundated by standing or slowly moving water where the water remains within the plant root zone for most of the growing season. They contain mainly emergent vegetation and the water is usually nutrient-rich. Marshes may contain small areas of shallow open water.

peatland: A wetland commonly referred to as muskeg, at term that includes permanent bogs, fens, swamps, and any contained area of shallow open water bodies. They are characterised by the accumulation of peat-derived from plant materials such as mosses and sedges.

shallow open water: Wetlands that are intermittently or permanently flooded, or that have seasonally stable water regimes where the water is less than two metres deep. Generally, there are open expanses of standing or flowing water, although submerged or floating vegetation may be present.

swamp: A wetland that is inundated at least seasonally by standing or slow-moving water. The vegetation consists of a dense cover of trees or shrubs.

Wetlands Value An attribute, feature, characteristic, activity, expression or function of a wetlands that has worth to some segment of society, whether or not that worth can be measured economically.

Zooplankton Animal life, usually microscopic, found floating or drifting in the water column of oceans or bodies of fresh water; form the bulk of the primary consumer link in aquatic food chain. Zooplankton form the link between primary producers (phytoplankton) and the higher trophic levels (e.g., fish, humans).

APPENDICES

LIST OF APPENDICES

APPENDIX A

OIL SANDS WETLANDS WORKING GROUP MEMBERS

APPENDIX A: OIL SANDS WETLANDS WORKING GROUP MEMBERS

Name	Affiliation	Areas of Expertise
Linda Halsey	University of Alberta Department of Biological Sciences	Peatland Ecology and Development
Steve Tuttle	Suncor Energy Inc.	Industry, Mine Planning and Land Reclamation
Terry Van Meer	Syncrude Canada Ltd.	Industry, Mine Planning and Land Reclamation
Judith Smith	Shell Canada Ltd.	Industry, Mine Planning and Land Reclamation
Ian Mackenzie	Mobil Oil Canada Properties.	Industry, Environmental Planning
Neil Chymko	Alberta Environment (Environmental Service)	Regulatory, Land Reclamation and Aquatic Biology
Dale Adams	Alberta Environment (Natural Resources Service, Water Management Division)	Regulatory, Water Management
John Martin	Alberta Environment (Natural Resources Service, Fish and Wildlife Division)	Regulatory, Wildlife Habitat
Chris Hale	Alberta Environment (Land and Forest Service)	Regulatory, Forestry, Land Management and Land Reclamation
Leonard Leskiw	Can-Ag Enterprises	Consultant, Soil Development
Peter Nix	Golder Associates	Consultant, Aquatic Biology and Wetlands Ecology
John Gulley	Golder Associates	Consultant, Wetland Reclamation and Research
Ken Lumbis	Ducks Unlimited	Consultant, Wildlife Habitat (Waterfowl)
Tony Punko	Athabasca Chipewyan First Nation	Consultant, Traditional Land Use
Lynne Kemper	Kemper^2 & Associates	Consultant, Environmental Sciences and Policy
Carl Surrendi	Ft. McKay First Nation	Consultant, Traditional Land Use

APPENDIX B

NATURAL WETLANDS IN THE OIL SANDS REGION

APPENDIX B

NATURAL WETLANDS IN THE OIL SANDS REGION

TABLE OF CONTENTS

FIGURES

TABLES

APPENDIX B: NATURAL WETLANDS IN THE OIL SANDS REGION

Linda Halsey
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1. Classification and Ecology

A wetland is any land 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 that are adapted to a wet environment (National Wetlands Working Group 1988). The environmental processes that control wetland development form hydrologic, chemical, and biotic gradients and commonly have strong cross-correlations. These interrelated gradients are represented by five wetland classes, of which three are non-peat forming wetlands generally having < 40 cm of accumulated organics and two are peatlands with > 40 cm of accumulated organics. Non-peat forming wetlands are subdivided into: 1) shallow open water, 2) marsh, and 3) swamp; peatlands can be subdivided into 1) fen and 2) bog (Figure B1). This primary wetland subdivision forms the foundation for defining Alberta's wetlands (Alberta Environmental Protection 1997) and Alberta's wetland policy (Alberta Water Resources Commission 1993).

Shallow Open Waters are non-peat forming wetlands that are characterized by aquatic processes confined to less than 2 m depth at midsummer. These wetlands have submergent to floating vegetation and form a transition to truly aquatic ecosystems. The chemistry of this wetland class is variable and does not distinguish it from the remaining four wetland classes. Floristic composition is dependent on chemical conditions.

Marshes are open, non-peat forming wetlands that are dominated by sedges (Cyperaceae) and other monocots. Marshes are characterized by seasonal water level fluctuations, relatively high amounts of water flow, and are influenced by ground and surface waters. As a result, concentrations of nitrogen and phosphorus are high, leading to abundant vascular plant production; however, peat accumulation is limited by high decomposition rates. Mosses are generally lacking or not abundant as they do not compete well with rapid vascular plant growth and do not tolerate large fluctuations in seasonal water levels. As with shallow open waters, chemical differences in marshes strongly influence their floristic composition. Alkaline marshes (dominated by calcium and bicarbonate) are dominated by *Carex*, *Scirpus*, and *Typha*, whereas saline marshes (dominated by sodium and sulfate) are largely occupied by *Salicornia* and *Scirpus*.

Swamps are forested, wooded or shrubby non-peaty wetlands. Swamps and marshes have a poorly developed bryophyte layer that results from strong seasonal water level fluctuations and high vascular plant production. Peat accumulation is limited in swamps as decomposition rates are high. Vegetatively swamps are quite diverse and in Alberta may be composed of some combination of *Larix laricina*, *Picea mariana*, *Betula*, and *Salix*.

Peatlands, often termed muskeg, differ from non-peat forming wetlands by a combination of interrelated hydrologic, chemical, and biotic factors that results in a decrease in decomposition relative to plant production allowing for the accumulation of peat. Peatlands represent an important terrestrial carbon sink, with an estimated 455 Pg currently stored (Gorham 1991; 1 Pg = 10^{15} g) or 25% or the world's terrestrial carbon (Woodwell and Houghton 1991). The amount of carbon stored in peatlands is roughly equivalent to 75% of the total amount of global atmospheric carbon.

The initiation of peat accumulation is related to stabilization of seasonal water levels and restriction of water flow through a wetland which, in conjunction with leaching of salts from the mineral substrate, allows for the establishment and development of a moss layer. The stabilization of regional water tables appears to have been an important component in the successional change from prairie marshes to boreal fens in the western interior of Canada over the past 10,000 years (Zoltai and Vitt 1990).

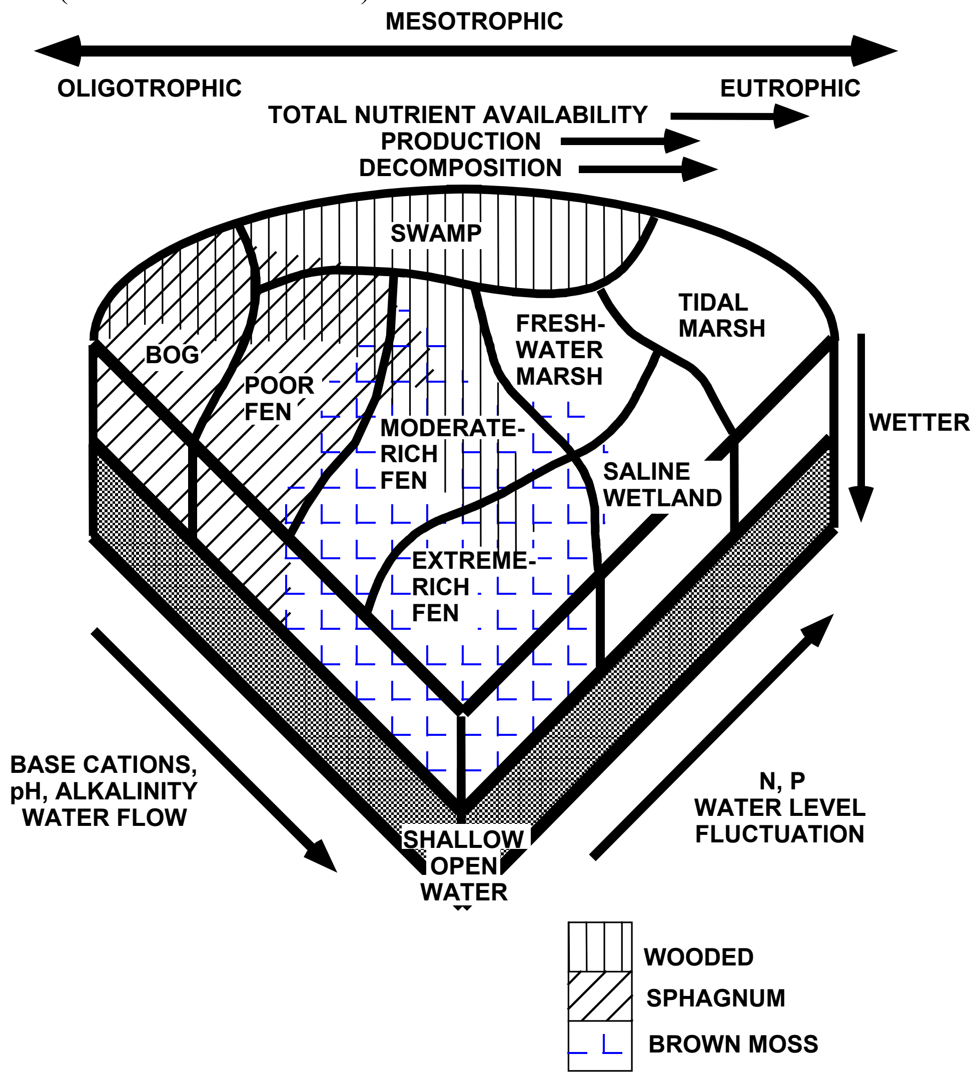
The establishment of a moss layer results in the accumulation and maintenance of nutrients in a nonavailable form, reducing vascular plant production. Stabilized water levels, anaerobic conditions, and decreased nutrient availability lead to a substantial decrease in decomposition rates. This results in the development of peat accumulating ecosystems (Vitt and Kuhry 1992). Alberta peatlands are classified into geogenous fens and ombrogenous bogs, each with distinctive indicator species, acidity, alkalinity, and base cation content (Figure B1).

Fens are geogenous ecosystems that are affected by mineral soil waters (ground and/or surface) that may be relatively rich in mineral elements. Fens can be subdivided on the basis of hydrology into: soligenous and largely influenced by flowing surface water; topogenous and largely influenced by stagnant ground water; or limnogeneous and largely influenced by associated lakes and ponds. All three fen types have water levels at or near the peat surface. Soligenous fens commonly have discrete patterns of open pools (flarks) alternating with elongate, shrubby to wooded ridges (strings) oriented perpendicular to the direction of surface water flow. These patterned fens may be either acidic or basic. Topogenous, limnogenous, and some soligenous fens are nonpatterned. Fens can be open and dominated by *Carex*, *Scirpus*, and *Eriophorum*; shrubby and dominated by *Betula* and *Salix*; or wooded to forested dominated by some combination of *Picea mariana*, *Larix laricina*, *Betula*, and *Salix*.

In the past, fens were subdivided on the basis of the number of indicator species: low for poor fens, high for rich fens. This gradient of indicator species correlates with a chemical gradient (Sjörs 1952). Poor fens are acidic (pH 4.5 to 5.5), poor in base cations and have no or little alkalinity. They are dominated by oligotrophic and mesotrophic species of *Sphagnum*. Moderate-rich fens have slightly acid to neutral pH (pH 5.5 to 7.0), low to moderate alkalinity, a ground layer of brown mosses (namely, *Drepanocladus*, *Brachythecium*, *Calliergonella*), and low abundances of mesotrophic species of *Sphagnum*. Extreme-rich fens have basic pH (above 7.0), high concentrations of base cations, and high alkalinity. They are characterized by species of *Drepanocladus*, *Scorpidium*, and *Campylium* and may contain marl deposits.

Bogs are ombrogenous peatlands that receive their surface water only from precipitation and have low water flow. The water table is generally 40 to 60 cm below the peat surface. For these reasons bogs are acidic ecosystems with pH below 4.5; they are poor in base cations and have no alkalinity. Bogs are dominated by oligotrophic species of *Sphagnum*, feather mosses *Pleurozium schreberi* and *Hylocomium splendens*, and lichens of *Cladonia* and *Cladina*. They may be open, wooded or forested with trees limited to *Picea mariana*. As a result of the low thermal conductivity of dry *Sphagnum*, bogs have lower surface water temperatures than other surrounding organic and nonorganic soils. Permafrost is consequently restricted to bogs at its southern limit, where it forms peat plateaus and palsas (Vitt et al. 1994).

Figure B1. Ternary Diagram of Wetland Classes and Their Relationship to Chemical and Biotic Gradients
(Modified from Vitt 1994)

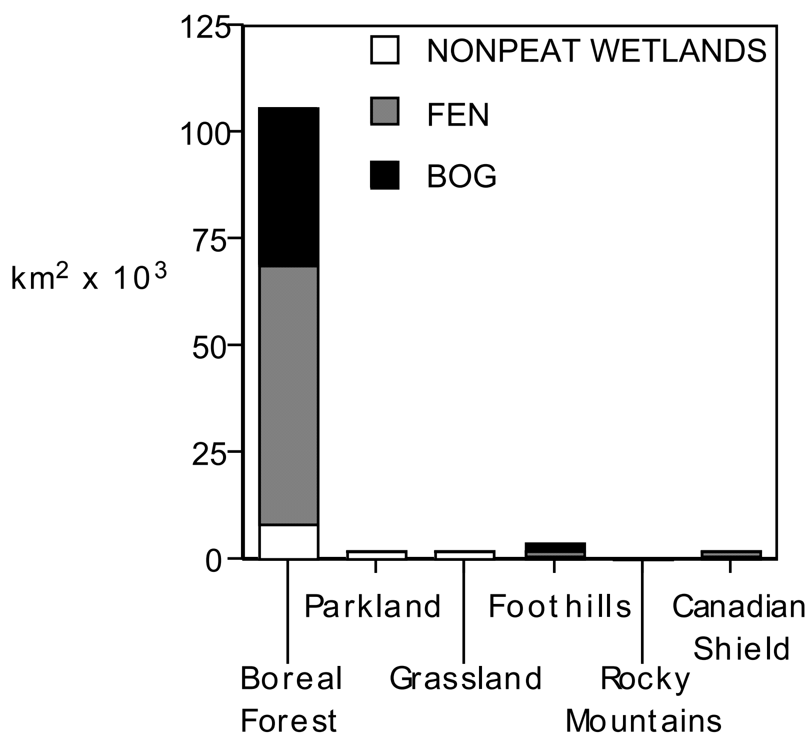


Peatlands form through the lateral expansion of peat over upland areas (paludification) or through infilling of lakes (terrestrialization) (NWWG 1988). Paludification occurs as a result of a rise in the regional water table induced by climatic change or mediated by local peat build-up. Terrestrialization results from sediment and peat infilling a water-filled depression, with aquatic habitats gradually becoming drier. Eventually, the original lake or waterbody can be completely covered with peat. In both scenarios (paludification and terrestrialization), large vegetation changes are evident (NWWG 1988). At the same time, chemical changes occur in the peatland due to peat build-up, isolating the surface from the underlying substrate, as well as through the processes of oligotrophication and acidification (Vitt 1994). Acidification produces complete changes in species, with nutrient stress also causing many species to be replaced by others more tolerant to oligotrophy or nutrient poor conditions (Vitt 1994). Typical successions begin with moderate-rich fens that become progressively poorer as *Sphagnum* invades (Vitt and Kuhry 1992). Bogs represent the "climax" of the succession, with permafrost developing in climatically conducive areas (Vitt et al. 1994). Depending on allogenic factors, succession may begin or end at any phase of this sequence (Vitt and Kuhry 1992). Secondary internal developmental processes in both paludified and terrestrialized peatlands result in patterning, pool development, and the differentiation of hummocks and hollows (Vitt and Kuhry 1992).

2. Natural wetlands: Types and Distributions

Approximately 114,000 km^2 of wetlands occur in Alberta, representing 18.0% of the province's landbase (AEP 1996, Vitt et al. 1996). Most of these wetlands are peatlands (90.4%) found mainly within the Boreal Forest Natural Region (Figure B2), representing 11.3 Gtonnes of stored carbon (Halsey and Vitt, unpublished data). Nonpeat accumulating wetlands dominate the Parkland and Grassland Natural Regions (Figure B2). The distribution and type of wetlands found within the province is controlled mainly by climate, specifically mean annual temperature and thermal seasonal aridity index (TSAI - total annual precipitation/mean growing season temperature) (Vitt et al. 1996). TSAI has also been identified as the primary factor controlling the southern limit of peatlands (Halsey et al. 1998).

Figure B2. Wetlands in Alberta by Natural Region
(Data from Vitt et al. 1996, AEP 1996)



The presence or absence of salts within the substrate is also a significant variable explaining wetland variation across the province. Areas of equivalent climates have much higher amounts of non-peat accumulating wetlands when associated with solonetzic soils (Vitt et al. 1996). This can be related to the inability of mosses to establish viable communities in areas associated with salinity (Vitt et al. 1993).

Substrate texture and topography as well as bedrock geology have also been identified as important controls on wetland type and distribution (Halsey et al. 1997). Substrates with high hydraulic conductivity support patterned fens in climatically conducive areas, while nonpatterned fens and bogs are associated with substrates of relatively low hydraulic conductivity. Wetlands are extensive in areas with minimal topography and poorly integrated drainage, particularly along major drainage divides such as Alberta's northern uplands. Cover values are low in areas of steep slopes found along Alberta's foothills (Vitt et al. 1996). With respect to geoology, acidic bedrock supports higher bog cover than calcareous bedrock where fens dominate (Halsey et al. 1997).

Since factors of climate and geology control wetland type and distribution, changes in these parameters lead to corresponding changes in wetland type and distribution. For example, climatic change during the Holocene led to climatic shifts in wetland distribution (Halsey et al. 1995; 1998), while climatic change predicted by greenhouse gas induced warming could have equally significant impacts on wetland distribution (Gorham 1991). Similarly, development of oil sands leases will significantly alter landscape structure with wetland reclamation goals constrained by this new landscape. Wetland types in the reclaimed landscape may be significantly different than those present prior to mining as the geologic factors controlling wetland distribution are changed.

3. Natural Wetlands: Classification and Properties

Table B1 provides information on wetland classification according to the Alberta Wetlands Inventory and Ecosites of Northern Alberta. Table B2 describes properties of the various types of wetlands.

Table B1. Comparison of Alberta Wetlands Inventory (AWI) Forest Classification and the Field Guide to Ecosites of Northern Alberta

ALBERTA WETLANDS INVENTORY[(a)]			FIELD GUIDE ECOSITES[(b)]
CLASS	SUBCLASS		
Shallow open water (W)	n/a	n/a	n/a
Marsh (M)	n/a	n/a	Marsh (l1)
Swamp (S)		Coniferous swamp (Stnn and Sfnn)	Wetter end of horsetail (f)
		Deciduous Swamps (Sons)	any upland ecosites phases
Fen (F)	Open fen (≤10% tree cover)	Patterned fen (Fop)	
		Non-patterned shrubby fen (Fons)	Shrubby poor fen (j2) and shrubby rich fen (k2)
		Non-patterned graminoid fen (Fong)	Graminoid rich fen (k3)
	Wooded fen (>10% - ≤70% tree cover)	No internal lawns (Ftnn)	Treed poor fen (j1) and treed rich fen (k1)
Bog (B)	Wooded bog (>10%, ≤70% tree cover)	No internal lawns (Btnn)	Treed bog (i1) and shrubby bog (i2)

(a) Halsey and Vitt 1996
(b) Beckingham and Archibald 1996.
n/a = not applicable.

Table B2. Summary of General Wetland Types and Their Properties

Properties	Bogs	Fens	Marshes	Swamps	Shallow Open Water
Peat-forming	yes (*Sphagnum*)	yes (sedges, brown moss)	no	no	no
pH	strongly acidic	acidic to neutral	neutral to slightly alkaline	neutral to moderately acidic	variable
Water Level	near surface	at or near surface	fluctuates seasonally	at or near surface	intermittent or permanently flooded
Flowing Water	no	yes	yes	yes	yes
Nutrients	variable	variable	high	high	variable
Minerals	low	low to high	medium	medium	high
Dominant Vegetation	*Sphagnum*, ericaceous shrubs	sedges, brown moss or *Sphagnum* moss	emergent sedges, grasses, rushes, reeds, submerged and floating aquatics	deciduous or coniferous trees or shrubs, herbs	emergent or submerged vegetation

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APPENDIX C

LANDSCAPE DESIGN CONSIDERATIONS FOR WETLAND CREATION

APPENDIX C

LANDSCAPE DESIGN CONSIDERATIONS FOR WETLAND CREATION

TABLE OF CONTENTS

FIGURES

TABLES

APPENDIX C: LANDSCAPE DESIGN CONSIDERATIONS FOR WETLAND CREATION

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1. Upland to Wetland Ratio

The amount of upland area necessary to provide an adequate watershed for created wetlands is an important design consideration. The upland to wetland ratio is important because it affects the hydrologic characteristics of wetlands developing within the watershed.

A ratio between 8:1 to 10:1 has been reported to provide an adequate watershed to sustain the hydrologic requirements of wetlands near Saskatoon (Dr. Barbour, pers. comm.). A study on drainage potential of agricultural lands in central and northern Alberta also provides information on natural upland to wetland ratios (Table C1).

In the oil sands region, future research needs to be conducted to determine the upland to wetland ratios required for wetland creation within the different upland landforms.

Table C1. Wetland Inventory of Agricultural Lands in Central and Northern Alberta

Basin	Location	Parent Material	Area (acres)	Permanent Wetlands (%)	Non-Permanent Wetlands (%)
Silver Creek	Camrose	Moraine	34 000	4	11
Lalby Creek	Falher	Glaciolacustrine	45 000	8	20
Dunvegan Creek	Spirit River	Glaciolacustrine	36 000	1	10
Shoal Creek	Athabasca	Till, glaciolacustrine and organic	61 000	27	20
Tee Pee Creek	High Level	Glaciolacustrine and organic	40 000	20	8

Source: Alberta Water Resources Commission 1987

2. Water Balance and Surface Drainage

A review of the literature on wetland creation indicated very few studies exist and no study specific to the boreal forest has been conducted. We are extrapolating information from two North American studies on the basis of principles and patterns that appear to be consistent across widely different ecoregions. Two studies comparing created wetlands with their design and construction plans indicated that most plans gave little consideration to the hydrology of the wetland (Confer 1990; Gwin and Kentula 1990). Both studies reported that the proportion of created wetlands inundated with open water was considerably greater than that of natural wetlands. This discrepancy is quite startling since upland hydrology is a significant factor controlling wetland type and function. Both studies clearly demonstrate the need to establish and document target upland hydrologic requirements prior to construction in order to achieve and determine successful wetland creation.

In the oil sands region, the understanding and quantification of water balances of the different landforms in upland areas (i.e., overburden disposal areas, tailing sand storage areas and CT deposits) will increase the probability of successful wetland creation. The water balance of each landform will provide hydrologic design criteria for wetlands receiving waters from them. Because a water balance is based on inflows equaling outflows, great care must be taken to ensure all components of the equation are accurately measured and potential errors and their causes are estimated. A water balance equation from Kentula et al. (1992) is as follows:

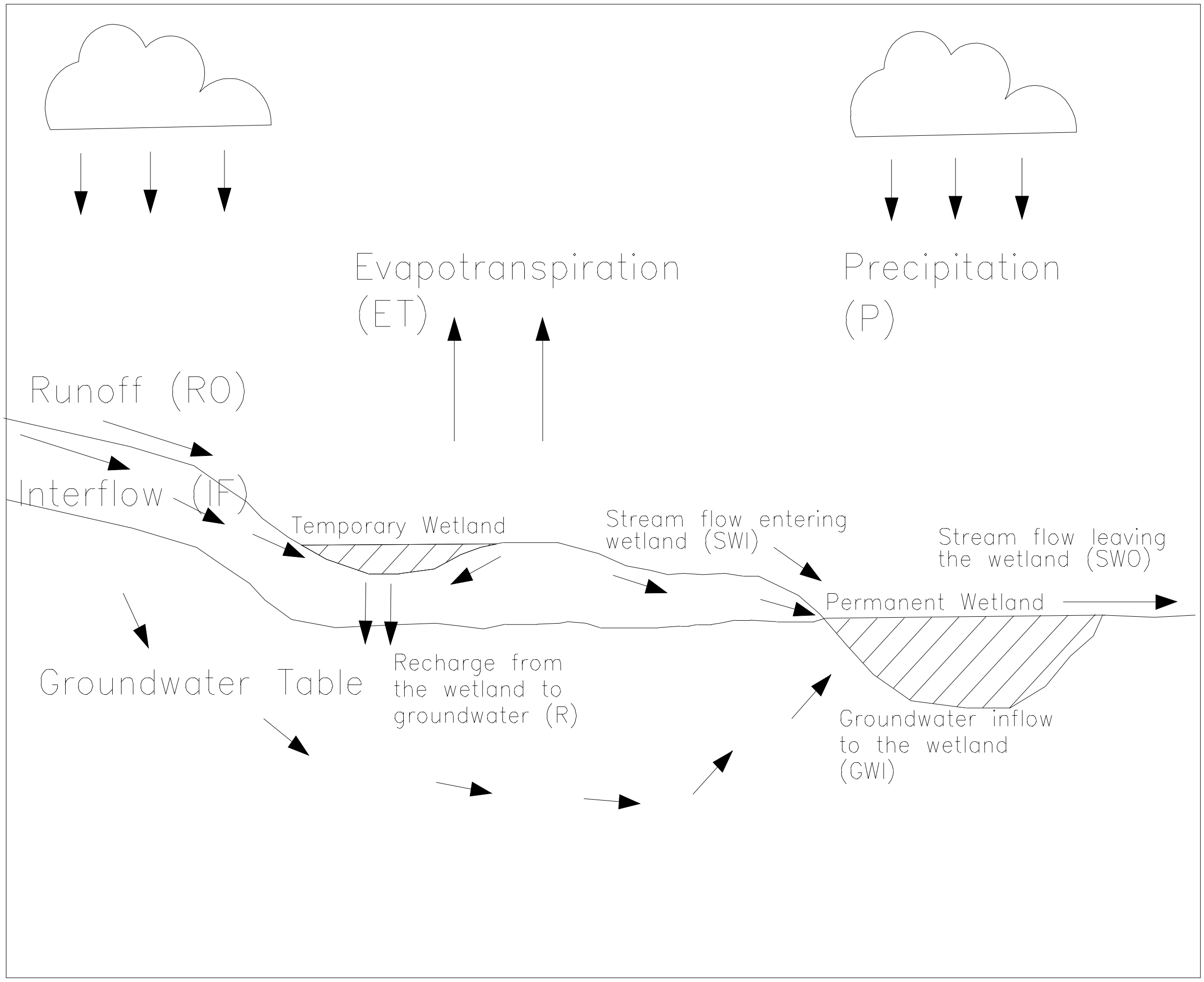
$$P + RO + IF + SWI + GWI = ET + SWO + R$$

where:

P = precipitation on the wetland
RO = runoff
IF = interflow
SWI = stream flow entering the wetland
GWI = groundwater inflow to the wetland
ET = evapotranspirative losses from the wetland
SWO = stream flow leaving the wetland, and
R = recharge from the wetland to groundwater.

Linkages between the components of the water balance equation and wetlands within the landscape are shown in Figure C1.

Figure C1. Schematic Diagram of the Water Balance Equation



In the oil sands region, various materials compose the natural and reclaimed upland soils and landforms (Tables C2 and C3). The following are brief descriptions of these reclamation materials.

Peat-Mineral Mix

- A peat-mineral mix is a mixture of peat and mineral material that is replaced on the landscape resulting in a “mineral soil” or “cover soil”at the surface (topsoil). It is obtained by either overstripping peat into the mineral soil or by placing peat material and then rotovating into the underlying mineral material.

Glaciolacustrine (Pl)

- Glaciolacustrine (Pl) is clayey material of glaciolacustrine (and morainal) origin used as subsoil with a peat-mineral mix capping, or if organic carbon is >2 %, it may be used as both surface soil and subsoil.

Glaciofluvial (Pg)

- Glaciofluvial (Pg) is sandy material of glaciofluvial origin used as subsoil with a peat-mineral mix capping, or if organic carbon is >2 %, it may be used as both surface soil and subsoil. Texture is loamy fine sand to sandy loam, structureless, no strata of fine material and non-compact.

Overburden (OB)

- Overburden (OB)is material that is obtained from below the natural soil profile and extends to the oil sands formation that is mined. It includes till, fluvial, lacustrine and residual materials that may be oily. Overburden texture is usually sandy loam, clay loam or sandy clay loam and has a significant oil content (usually < 2%, but as high as 6 %). Saline and sodic conditions may also occur in some overburden. For reclamation, overburden may be used as subsoil or placed below the soil profile.

Tailings Sand (TS)

- Tailings Sand (TS) is fine sand material that is one of the final products of the hydrocarbon extraction process.

Direct Placement

- This is soil developed on Pl or Pg material that is salvaged from the natural landscape and directly placed on the reclaimed landscape. The goal is to achieve > 2 % organic carbon (LFH and/or peat).

Differences in the physical and chemical properties of these reclamation materials and their relative position within the landscape will significantly affect the water balance of upland areas. Key physical and chemical properties of various reclamation materials in the oil sands region are given in Table C4.

Table C2. Natural Upland Landscapes and Soils in the Oil Sands Region

LANDSCAPE					SOIL		
Substrate Type	**Surface Expression**	**Slope**	**Relief**	**Capability**	**Subgroup**	**Moisture**	**Capability**
Eolian sand	Dunes	< 15 %	5 to 15 m	1	Dystric Brunisols	Subxeric & Submesic	4
					Gleyed Dystric Brunisols	Subhygric	3
	Undulating plains	< 15 %	< 5 m	1	Orthic and Peaty Gleysols	Hygric [a]	4
Fluvial	Floodplains	< 5 %	< 5 m	1	Orthic Regosols	Mesic	2
					Gleyed Regosols	Subhygric	1
	Terraces	< 5 %	< 5 m	1	Orthic and Peaty Gleysols	Hygric [a]	4
Glacio-fluvial	Meltwater channels	< 9 %	< 5 m	1	Dystric and Eutric Brunisols	Submesic & Mesic	3 & 4
					Gleyed Brunisols	Subhygric	2 & 3
					Orthic and Peaty Gleysols	Hygric [a]	4
Glacio-lacustrine	Plains	< 5 %	< 2 m	1	Orthic Gray Luvisols	Mesic	2
					Gleyed Gray Luvisols	Subhygric	1
					Orthic and Peaty Gleysols	Hygric [a]	4
Morainal	Undulating to rolling slopes	5 to 30 %	5 to 50 m	1 to 2	Orthic Gray Luvisols	Mesic	2
					Gleyed Gray Luvisols	Subhygric	1
					Orthic and Peaty Gleysols	Hygric [a]	4
Rough broken	Steep river banks	16 to 70 %	5 to 100 m	2 to 5	Regosols	Submesic & Mesic	3 & 4
					Brunisols	Subhygric	2 & 3
					Luvisols	Hygric [a]	4
Organic	Bogs with high water table	< 2 %	level	1	Typic & Terric Mesisols Fibrosols	Subhygric	5
	Fens with high water table	< 2 %	level	1	Typic & Terric Mesisols Humisols	Subhygric	5

Source: Leskiw and Moskal 1997a, b
[a] Hygric aerated is Class 2 or 3; hygric reduced is Class 4

Table C3. Reclaimed Landscapes and Soils in the Oil Sands Region

LANDSCAPE					SOIL		
Substrate Type	**Surface Expression**	**Slope**	**Relief**	**Capability**	**Soil Type**	**Moisture**	**Capability**
Overburden (salt free, saline or sodic) with soil capping	Side walls	16 to 40 %	5 to 100 m	2 to 3	Peat-mineral mix over overburden	Mesic	3
						Subhygric	2
					Peat-mineral mix over subsoil o n overburden	Mesic	3
						Subhygric	2
	Near level surfaces	< 2 %	< 5 m	1	Peat-mineral mix over overburden	Mesic	3
						Subhygric	2
						Hygric [a]	4
						Subhydric & Hydric	5
					Peat-mineral mix over subsoil on overburden	Mesic	3
						Subhygric	2
						Hygric [a]	4
						Subhydric & Hydric	5
Tailings sand with soil capping	Side walls	16 to 40 %	5 to 100 m	2 to 3	Peat-mineral mix over tailing sand	Submesic & Mesic	3
						Subhydric	2
					Peat-mineral mix over subsoil on tailing sand	Submesic & Mesic	3
						Subhydric	2
					Peat-mineral mix over tailing sand	Mesic	3
						Subhygric	2
	Near level surfaces	< 2 %	< 5 m	1		Hygric [a]	4
						Subhydric & Hydric	5
					Peat-mineral mix over subsoil on tailing sand	Mesic	3
						Subhygric	2
						Hygric [a]	4
						Subhydric & Hydric	5
CT material covered with overburden and soil capping	Near level surfaces	< 2 %	< 5 m	1	Peat-mineral mix over overburden covering CT		
CT material covered with tailing sand and soil capping	Near level surfaces	< 2 %	< 5 m	1	Peat-mineral mix over tailing sand covering CT		

Source: Leskiw and Moskal 1997c, d
[a] Hygric aerated is Class 2 or 3; hygric reduced is Class 4

Table C4. Key Physical and Chemical Properties of Reclamation Materials in the Oil Sands Region

Material	pH[1] (H_2O)	EC[1]	SAR[1]	Texture[1]	Hydraulic Conductivity[2] (cm/hr)	AWHC[3] (mm/cm)
Peat-Mineral Mix	7.4 (7.1 – 7.8)	1.0 (0.2 – 4.3)	0.5 (0.2 – 0.7)	ptL, ptSL, ptLS	15 – 50	1.7
Glaciolacustrine (Pl)	7.5 (7.4 – 7.9)	1.0 (0.4 – 3.0)	0.4 (0.2 – 0.6)	SiCL, CL, C	0.5 – 1.5	1.6
Glaciofluvial (Pg)	7.5 (7.4 – 7.8)	1.0 (0.4 – 3.0)	0.2 (0.1 – 0.5)	L, SL, LS, S	1.5 – 5	1.3
Overburden • glacial origin	7.5 (7.0 – 7.6)	3.0 (1.0 – 7.0)	5 (0.1 – 9.0)	CL, SCL, L, SL	0.05 – 0.15	1.5
Bedrock Formations • Clearwater Formation	7.5 (4.3-8.5)	9.9 (3.3-14.9)	26 (14.3-47.2)	SiC, CL, C, SCL		
Tailings Sand	7.5 (6.0-7.9)	0.5 (0.2-3.0)	0.5 (0.2-1.1)	fine sand	5 – 15	1.0

Sources: [1] Leskiw and Moskal 1997c, d, [2] McKeague, Wang and Coen 1986, [3] Leskiw 1998

To date, limited research has been conducted to understand upland hydrology and it impacts on wetland creation in the oil sands region. Future research needs to quantify the water balances for the different upland landforms. As well, research needs to be conducted to understand how various reclamation materials and practices affect upland hydrology and wetland creation.

With limited research, initial recommendations include the creation of intensive drainage networks within each watershed since it tends to increase surface runoff and decrease groundwater recharge. Erosion also tends to be less within a watershed when there are a large number of small drainage courses versus a few large watercourses per unit area. Continuity of wetlands and watercourses is also essential to creating corridors for some wildlife species. As well, wetlands basin design is an important consideration. Closed basins tend to create temporary wetlands with considerable water level fluctuation. They also tend to increase groundwater recharge and raise the water table. The optimum proportion of “closed basins” depends on the objectives. Nevertheless, a target of < 20 % closed basins is suggested at this time.

3. Slope Design

Bank slopes of wetlands greatly influence the type and extent of wetland created. Specifically, the slope angle leading into the wetland from the upland area influences the extent of the wetland vegetation established. Steep slopes provide minimal area with water depths ideal for wetland vegetation establishment and result in a narrow ring of vegetation at the water’s edge. Meanwhile, gentler slopes allow for the development of a wider expanse of wetland vegetation.

Although the data on wetland slope design reported in the literature are not from wetlands found in the boreal forest, the information applies to wetland creation in the oil sands region. Data collected from created wetlands in Oregon (Gwin and Kentula 1990) and Connecticut (Confer and Niering 1990) indicate that a large proportion were built with steep slopes, and consequently only narrow fringes of hydrophytic vegetation at the water's edge became established. These created wetlands had notably greater areas of open water than did similar natural wetlands sampled in the region. The large area of open water and steep bank slopes of these projects resulted in the creation of ponds, rather than the palustrine emergent marshes that were originally planned.

To provide sufficient area for wetland vegetation to develop, most experts recommend that bank slopes for created wetlands range between 5H:1V to 15H:1V (Kentula et al. 1992). However, recent research (Brown 1991, Gwin and Kentula 1990) indicates that bank slopes for most wetland types should be created at or beyond the gentle end of this range (near 15H:1V or flatter) to create wetlands similar to natural wetlands. Kentula et al. (1992) suggest that slopes of natural wetlands near the disturbance can be used as guides for contouring wetland projects.

Slope aspect also affects wetland creation. Slope aspect of >20% affects soil moisture regime, runoff potential and timing of runoff. Southeast to west aspects are warmer, drier, generate less runoff, and have earlier snow melt than east to northwest aspects. A variety of aspects in each watershed is preferred.

The recommendations above are for creating "ecological" wetlands that attempt to resemble natural wetlands in the reclaimed landscape. For other wetland types described in this document, such as "constructed" wetlands for flood control/flushing or water treatment, these recommendations may not apply.

4. Substrate

There are three main groups of substrates in the final reclaimed landscape. Their physical and chemical features affect surface runoff quantity and quality, as well as groundwater recharge and discharge rates and quality. Stability of these materials also impacts the final topography. Important characteristics of the substrates are discussed below.

4.1 Overburden

Overburden includes glacial materials (till, fluvial, lacustrine) and residual materials (Clearwater and McMurray Formations) overlying the oil sands (McMurray Formation) being mined. Glacial materials have variable textures. In general, till materials are clay loam to sandy clay loam, fluvial deposits are sandy to gravelly, and lacustrine deposits are clays. Permeabilities are variable and closely related to texture. Permeability decreases with increasing clay content and increasing density. Saline and sodic conditions occur and may result in the discharge of saline groundwater in seepage locations. Disturbed Clearwater Formation materials in the reclaimed landscape initially are a mass of “flakes” and “lumps” of dry fine textured sodic shale. In this state they are permeable. Once moistened the clays expand but as they become wetter, they are dispersed and rearranged into a configuration that is impermeable and has greater density. Subsidence occurs in the process and failures are likely to occur on slopes. Overburden derived from the McMurray Formation is an oily (2 to 6% hydrocarbon content) sandy material having slow to moderate permeability. All overburden materials are either stockpiled or used to construct dykes. Final landscapes are strongly sloping on dyke walls and nearly level to undulating elsewhere.

4.2 Tailings Sand

Tailings sand consists of the fine sand remaining after hydrocarbon removal. It is a loose, structureless, rapidly permeable, non-compacted material. Salts may be present in low amounts and they tend to be flushed through the permeable sands fairly quickly (1 to 3 years in the upper 1 meter). Tailings sands are used to construct dykes and they are also stockpiled in storage areas.

4.3 Consolidated/Composite Tailings (CT)

CT is a material created by the addition of gypsum to the slurry of mature fine tails stored in tailings ponds. Gypsum is applied to flocculate the dispersed fine clays resulting in a segregated mixture that allows water to drain, leaving a mass of mineral substrate called CT deposits. These are saline, oily fine sands with significant silts and clays. Initially the materials are wet and require several years to dry because the liquids and solids cannot be easily separated. Permeability rates are moderate to slow. High salinity is characteristic of CT deposits so any groundwater discharge will be saline. Subsidence will occur over time as the materials dry. Topography is nearly level to gently sloping (delta-like) created by discharge of CT from pipe outlets. Research is underway to develop procedures to stabilize and establish vegetation on the land surface.

During watershed design for wetland creation, rates of groundwater recharge and discharge can be managed by placing either a finer textured, less permeable capping (clay), or a sandy, permeable capping on any substrate material. As well, altering the slopes affects recharge and discharge. These alterations also affect surface runoff rates, watershed size requirements and wetland design. Compaction of soils, within the upper one meter, to reduce infiltration is not recommended as it will restrict root growth.

The substrate on which wetlands are created and their location within the landscape can influence their hydrology. Wetlands developed on coarse-textured substrates (e.g., tailings sand) may have difficulty maintaining sufficient water depth if the groundwater table is quite deep. Consequently, an impermeable liner (clay) needs to be installed to reduce permeability of the substrate and maintain water levels. Conversely, wetlands located within discharge areas regardless of the permeability of the substrate should not require a liner provided sufficient surface water or the groundwater maintains an adequate water depth for wetland creation. Beside water retention, the substrate texture also has a dramatic effect on vegetation establishment in created wetlands. Hammer (1989) rates substrate texture suitability for wetland establishment. Loamy soils are especially good because they are soft and friable, allowing for easy rhizome and root penetration. Fine textured soils such as clays may limit root and rhizome penetration. Although peaty organic soil supports wetland plants, he recommends not using pure peaty organic soil for wetland development. Peaty organic soil when flooded may become loose and provide inadequate support for emergent aquatics. According to Hammer's ratings, the peat-mineral mix used as a coversoil for reclamation in the oil sands region will provide a good substrate in terms of both nutrient balance and rooting medium quality.

5. Subsidence

Subsidence of mine spoils occurs as a result of a combination of three processes: self-load compression, hydro-compaction and macro-void migration as explained below (Cheel et al. 1994).

Self-load compression occurs on an area-wide basis and begins immediately after material placement. Spoil settles through compression from the weight of overlying spoil by: (1) crushing of fragments and (2) rotational reorientation of individual fragments in response to loading.

Hydro-compaction results from rewetting of spoil. When fragments of spoil material are originally disturbed they expand slightly in response to the release of stress. This slight expansion places the pore water under tension and the fragments become hard and strong. Upon rewetting the fragments swell and disintegrate. The weight of the overlying spoil crushes the fragments resulting in a volume reduction. Particles that are shed from the disintegrating fragments move downward, in response to gravity, to fill voids among larger fragments. This reduction in volume results in subsidence of the ground surface.

Macro-void migration produces sinkholes. They are the result of a particular interaction of large voids combined with self-load compaction and hydro-compaction. Large voids are formed around large angular blocks of spoil, by melting of frozen blocks or by hydro-compaction of loose spoil beneath a denser layer. The spoil above such a void arches so little deflection of the ground surface occurs. The void migrates upward through the spoil as the overlying spoil becomes wetted, slakes, and collapses into the void. The surface layer is commonly more compact because of the compactive effort of vehicle traffic. This surface commonly forms a beam-like layer spanning the growing void. When the surface layer becomes sufficiently undermined, it shears and falls into the void laving a distinct hole in the ground surface. The sinkhole soon fills with surrounding soil collapsing into the hole.

6. Erosion and Sedimentation

Erosion on upland areas contributes to sedimentation in wetlands and, if excessive, can be detrimental to wetland function. Several studies report that sediment loads (as low as 0.25 cm) significantly reduce the number of species and total number of individuals emerging from wetland seed banks (Galinto and van der Valk 1986, Jurik et al. 1994; Wang et al. 1994). The reduction of seedling emergence is generally related to seed mass, with larger seed size species showing the least effect of burial by sediment. These studies indicate the importance of minimizing erosion from upland areas and designing depositional areas within the landscape to reduce sediments entering wetlands. Tajek et al. (1985) categorize water erosion in Alberta as severe at 22 t/ha/yr. A study in Alaska reports a benchmark value for the accumulation rates of sediments in wetlands on undisturbed landscapes to be 0.3 cm/yr or less (van der Valk et al. 1983).

Within the oil sands region, erosion and sedimentation rates vary within the reclaimed landscape. Differences are due to several factors, including the texture of the soil capping material, slope angle, slope length and vegetation cover. Potential water erosion was calculated using the Universal Soil Loss Equation (Tajek et al. 1985) for the different vegetation covers present within reclaimed upland areas. These five vegetation covers include: (1) bare ground; (2) barley with tree seedlings; (3) sweet clover; (4) forest or (5) grassland. Each cover type represents a stage of succession towards either a mature forest or a grassland ecosystem. Besides vegetation cover, texture of soil capping material (coarse, medium or fine-textured), slope angle (1, 4, 10, 20 and 30%) and slope length (30, 50, 100 and 200 metres) were adjusted in the equation.

The Universal Soil Loss Equation is as follows:

$$A = R_T \times K \times LS \times C \times P$$

where:

A = average annual soil loss (t/ha/yr) R_T = rainfall and runoff erosivity factor (mm)
K = soil erosivity LS = slope length (m) and slope angle (%)
C = cover P = conservation practices

Calculations clearly indicate the need to have good vegetation cover (i.e., sweet clover, forest or grass) in order to prevent severe erosion and potential sedimentation into wetlands (Figures C1 and C2). Calculations indicate that if good vegetation cover is established on upland areas, erosion remains below the severe category even with slope angles as steep as 40% (22 degrees, 2.5H:1V)and slope lengths as long as 200 m. In terms of timing for wetland creation, this strongly suggests that wetland creation should begin after vegetation cover is well established in the adjacent upland landscape.

If well established vegetation cover is not possible prior to wetland creation, the following conditions apply to maintain erosion rates below the severe category: (1) upland areas seeded with barley and trees require slope angles < 12% and slope lengths < 200 m or (2) bare ground areas require slope angles < 7 % and slope lengths < 200 m. If either slope angle or slope length exceeds these values, a depositional area at the slope toe will have to be included in the landscape design in order to prevent sediments from entering wetlands.

Calculations also indicate texture, slope angle and slope length have a relatively minor impact on erosion rates as compared to vegetation cover. In addition to vegetation cover, creation of toe slopes between the base of strong slopes and wetlands is another effective method of attenuating sedimentation in wetlands.

Figure C2. Water Erosion Potential of a Loam Textured Soil Cap on a 100 m Slope as a Function of Slope Angle and Vegetation Cover

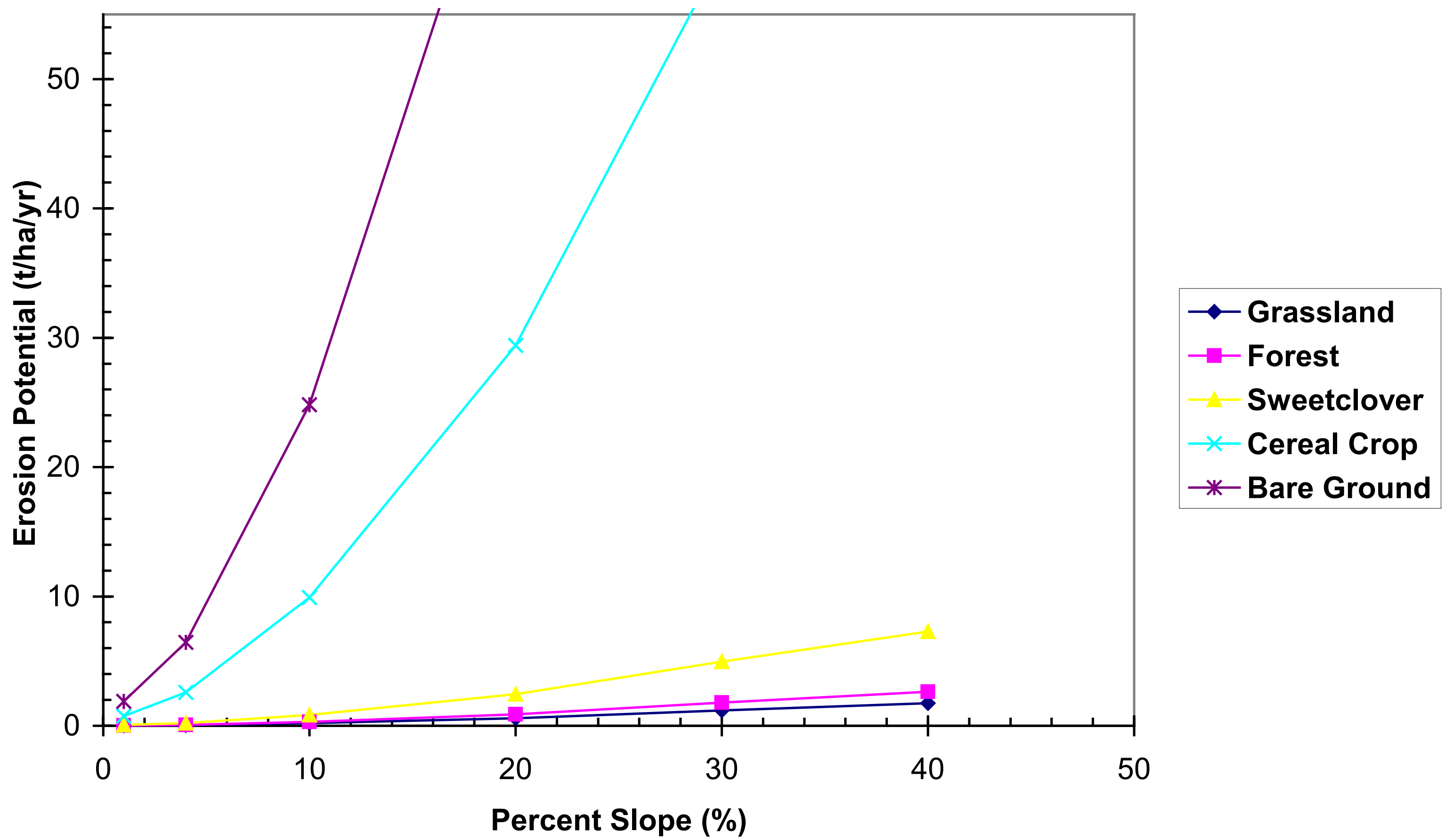
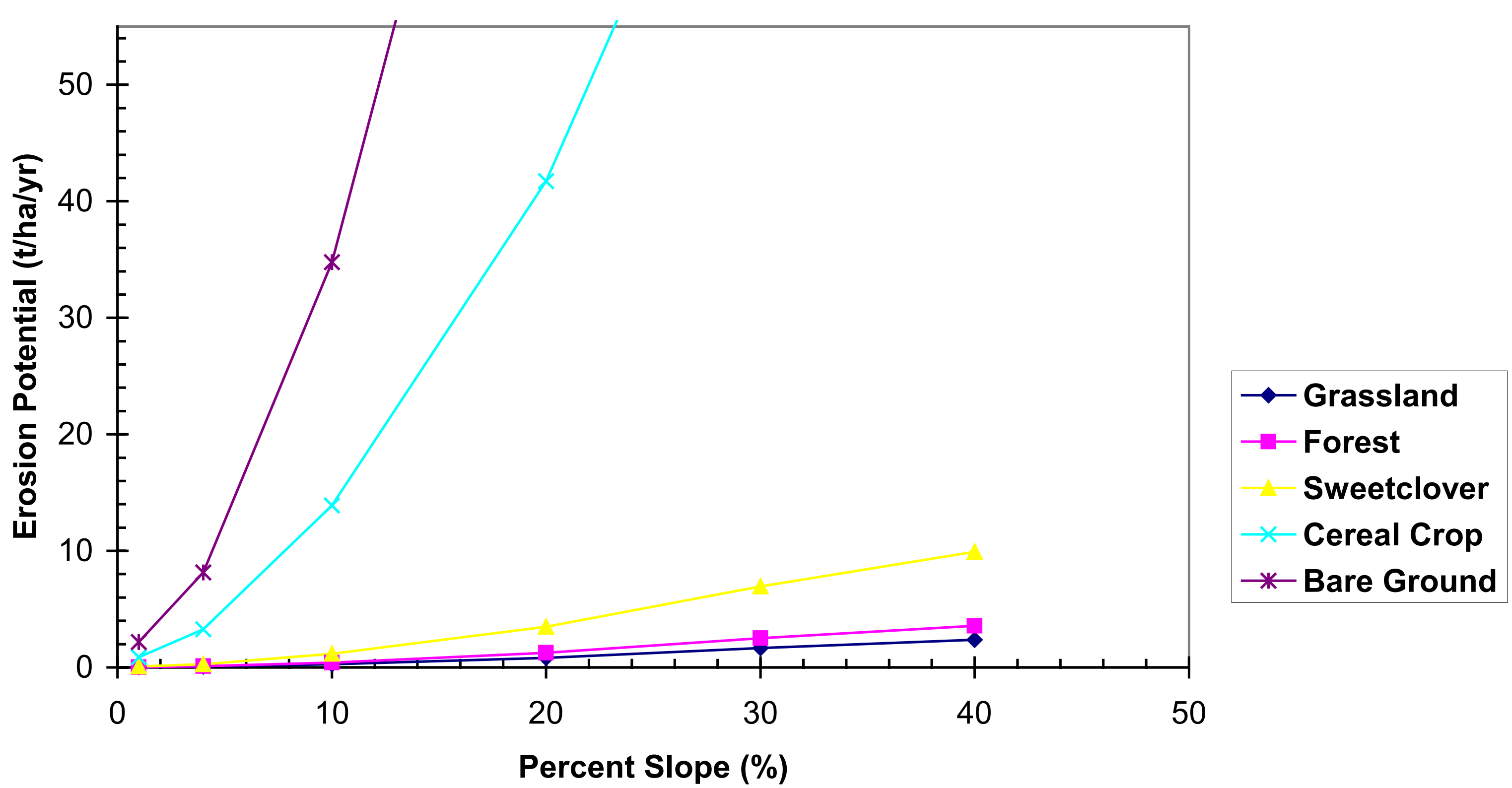


Figure C3. Water Erosion Potential of A Loam Textured Soil Cap on a 200 m Slope as a Function of Slope Angle and Vegetation Cover



7. Soil Organic Matter

Soil organic matter (SOM) serves important functions in wetland ecosystems that are fairly well documented in the literature. SOM is an important potential source of available nitrogen (Langis et al. 1991). SOM stores nutrients and provides organic substrates for bacteria involved in nitrogen fixation, denitrification and the sulfur cycle (PERL 1990). Organic soils also have higher cation exchange capacities, and consequently higher buffering capacity than do mineral soils (Brady 1974). Because organic matter has a high capacity to complex or adsorb metals and organics, the amount of organic matter in the substrate can influence a wetland's potential for pollutant retention.

Since SOM is a key component within a functional wetland ecosystem, it is important to understand the differences between organic soils of created wetlands and natural wetlands. Data collected in studies show that created wetlands have significantly lower SOM than natural wetlands. In an Oregon study, the average percent organic matter in soils of created wetlands (5.49% at 5 cm depth, S.E. =1.05%) was significantly lower than in soils of similar natural wetlands at depths of 5 cm (10.13%, S.E. =1.67%), 15 cm and 20 cm (Kentula et al. 1992). Due to the young age of the created wetlands, the lower amounts of organic matter were expected. Bishel-Machung et al. (1996) also determined natural wetlands had higher levels of organic matter and total nitrogen at a 5 cm depth than created wetlands, but had lower pH, bulk density and chroma.

The lower SOM of most created wetlands suggests that these soils have less energy for soil microbes to recycle and fix nitrogen and because of the low nitrogen inputs, plant growth is limited (Zedler and Langis 1991). As well, in systems with high nitrogen inputs, the lower organic matter in created wetlands limits their ability to process nitrogen through denitrification because of low carbon availability (Faulkner and Richardson 1991), thus constraining water quality improvements. Over time, one would expect the organic matter of soils of wetland projects to increase, however, because no studies in the literature have determined how long it takes organic soils to develop, Kentula et al. (1992) suggest enhancing the percentage of organic matter as the best way to accelerate and facilitate the development of wetland functions. Several studies have documented the use of organic soils and amendments to enhance wetland creation (Brown and Bedford 1997, Stauffer and Brooks 1997). In each study, organic soil from a donor wetland was used to augment the substrate of wetland projects in order to make the soils of the created wetland more similar to the natural wetland. Organic soil also provided a source of appropriate wetland plant propagules for revegetation. Brown and Bedford determined at both a small and large scale that transplanting organic soil (6 to 7 cm) from a remnant wetland significantly increases the number of wetland species and the amount of cover of wetland species. The study also reported that the number of plant species was higher in transplanted soil treatments versus the transplanted soil treatments which had plant roots and rhizomes removed. Their results indicate the plant materials in the organic soil are essential in enhancing revegetation of wetland ecosystems. In their recommendations, they advise against the long term storage of soil prior to replacement because of the reduced viability of rhizomes that result in a reduced number of successfully established species. Specifically, Brooks (1990) recommends organic soil should not be stockpiled longer than 30 days because of the possible oxidation of the soil, possible release of metals that may be toxic to seedlings and possible loss of viability of some seeds. Finally, Brown and Bedford recommend that replacement of organic soil should be concentrated at shallower elevations near the proposed high water table since observation of plant establishment was poor at water depths greater than 45 cm.

In Stauffer and Brook's study, organic soil was mixed with a loamy sand textured mineral soil (50% by volume) and replaced at a 15 cm depth. Treatments with the organic soil mixture had higher species richness, total vegetative cover and diversity (Shannon Index) versus the control. Soil treated plots initially had higher total nitrogen (mainly NO_3) and lower levels of phosphorus than control plots. However, pH was not significantly different between soil treated plots and the control. In their discussions, Stauffer and Brooks indicate that greater amounts of organic matter should have been added to the experimental plots so the levels matched those found in natural wetlands (15 to 20 %). They obtained organic matter levels as high as 5.5% in their study. Stauffer and Brooks recommend that existing mineral soils of a proposed wetland creation project should be analyzed to determine if organic soil or amendments are needed to promote the survival of planted vegetation. Based on comparisons with natural wetlands, they recommend that organic soil or amendments should be considered if the existing mineral soils at a created wetland project contains less than 10% organic matter.

In the oil sands region, a peat-mineral mix is currently used as a coversoil to reclaim upland areas. To achieve a minimum of 10% organic matter for wetland creation as recommended by Stauffer and Brooks (1997), a peat to mineral ratio of at least 1.5 to 1 is required according to the *Land Capability Classification for Forest Ecosystems in the Oil Sands Region - Revised Edition.* (Leskiw 1998). Testing is needed to confirm these values and their stability under wetland environments.

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APPENDIX D

HYDROLOGY AND VEGETATION CONSIDERATIONS FOR WETLAND CREATION

APPENDIX D

HYDROLOGY AND VEGETATION CONSIDERATIONS FOR WETLAND CREATION

TABLE OF CONTENTS

FIGURES

APPENDIX D: HYDROLOGY AND VEGETATION CONSIDERATIONS FOR WETLAND CREATION

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1. Water Depth and Flooding

Water depth and frequency of flooding are important in determining which plant species establish in created wetlands. Water depth creates different vegetation zones within a wetland in part because deeper water restricts oxygen from reaching the substrate. Water depth also influences the degree of light penetration and photosynthesis. According to Hammer (1989), these zones are defined with reference to the normal water level (0 cm) in the wetland and can be divided into deep (-91 to -152 cm); mid (-15 to -91 cm); shallow (-15 to +15 cm); and transitional (+15 cm to +45 cm) zones (Figure D1). The range in water depth between the deep and transitional zone (198 cm) indicates that the fluctuation of water depth must remain very small for successful wetland vegetation establishment and development. Since changes in water depth must remain relatively small, it becomes very important to understand the upland hydrology affecting water depth in created wetlands since fluctuation in water depth greater than 2 metres may pose serious problems for plants survival and composition.

Figures D2, D3 and D4 show natural and reclaimed soil-vegetation sequences typical for the boreal forest.

Besides water depth,factors such as the frequency, duration and seasonality of flooding are important for wetland vegetation establishment and development. Wetland species generally can withstand various degrees of flooding depending on when and for how long the flooding occurs. Many wetland species need a period of lower water level during the growing season, whereas in the dormant season, drawdown is not as critical.

2. Water Level Management

Water level influences plant survival and desired species composition. According to Hammer (1989), water level is the most critical aspect of plant survival during the first year after planting. A common misconception is to assume that because the plant is a wetland species, it can tolerate deep water. Frequently too much water creates more problems for wetland plants during the first growing season than too little water because plants do not receive adequate oxygen at their roots. Wetland emergent species should be planted in a wet substrate, but not flooded, and allowed to grow enough to generate a stem with leaves that protrude above the initial flooding height. For best survival and growth during the growing season, the substrate for small stalks (2 to 5 cm) should only be saturated, not flooded; and as the plants grow the water level can be raised proportionally. For species that grow in the shallow to transitional zones (Figure D1), watering during the first year should be limited to shallow sheetflow with intermittent drying periods, depending on the species, whereas, water levels for submergent and floating leaved aquatic plants should never be lowered to the extent that the plants become exposed. For submergent species, the most important criterion is maintaining water level stability and keeping the plant continuously submerged the first growing season. Besides encouraging the establishment of desirable plant species, water levels can be manipulated to control prolific growth and spread of weedy plants. For example, cattails may be controlled by deep flooding for several weeks during the growing season after the stems have been cut. Flooding may also inhibit establishment of undesirable opportunistic species.

Since management of water level in created wetlands is essential for plant establishment and development, wetland design may need to include mechanisms that ensure control of water levels.

Figure D1. Typical Wetland Plants by Planting Zone Related to Water Level in the Interior of the United States

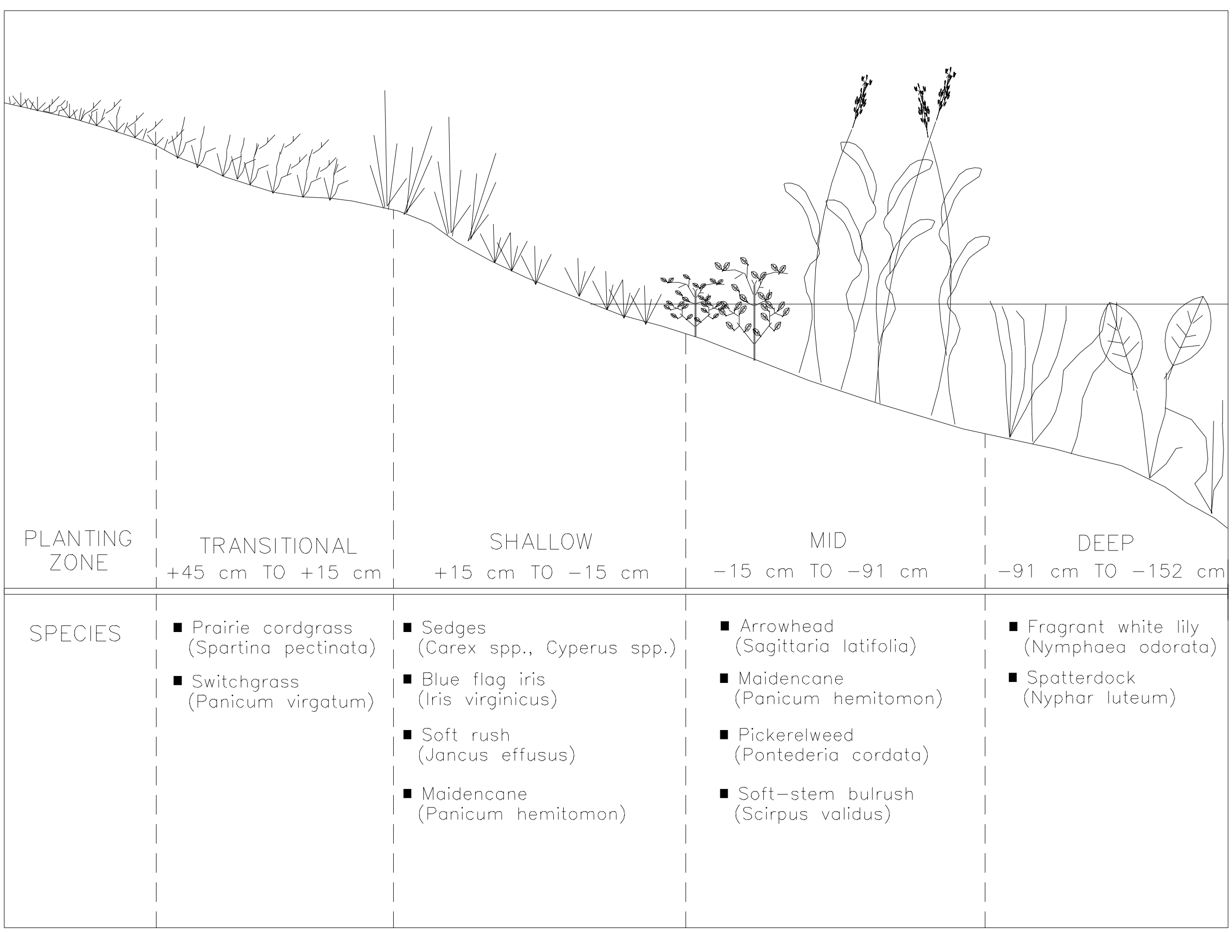


Figure D2. Natural Soil – Vegetation Relationship Typical for an Upland to Bog Sequence in the Boreal Forest

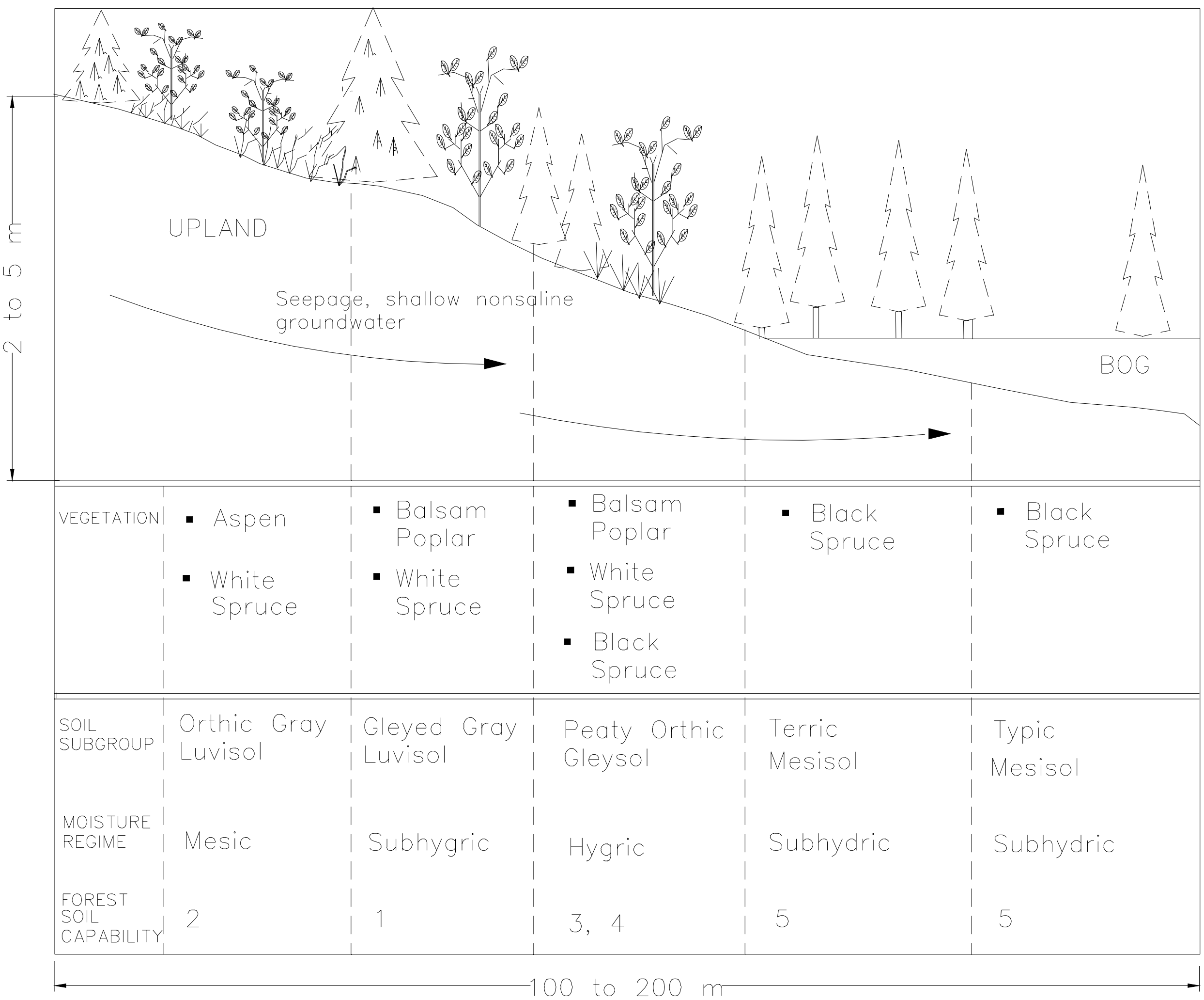


Figure D3. Expected Reclaimed Non-Saline Soil-Vegetation Relationships for an Upland to Wetland Sequence

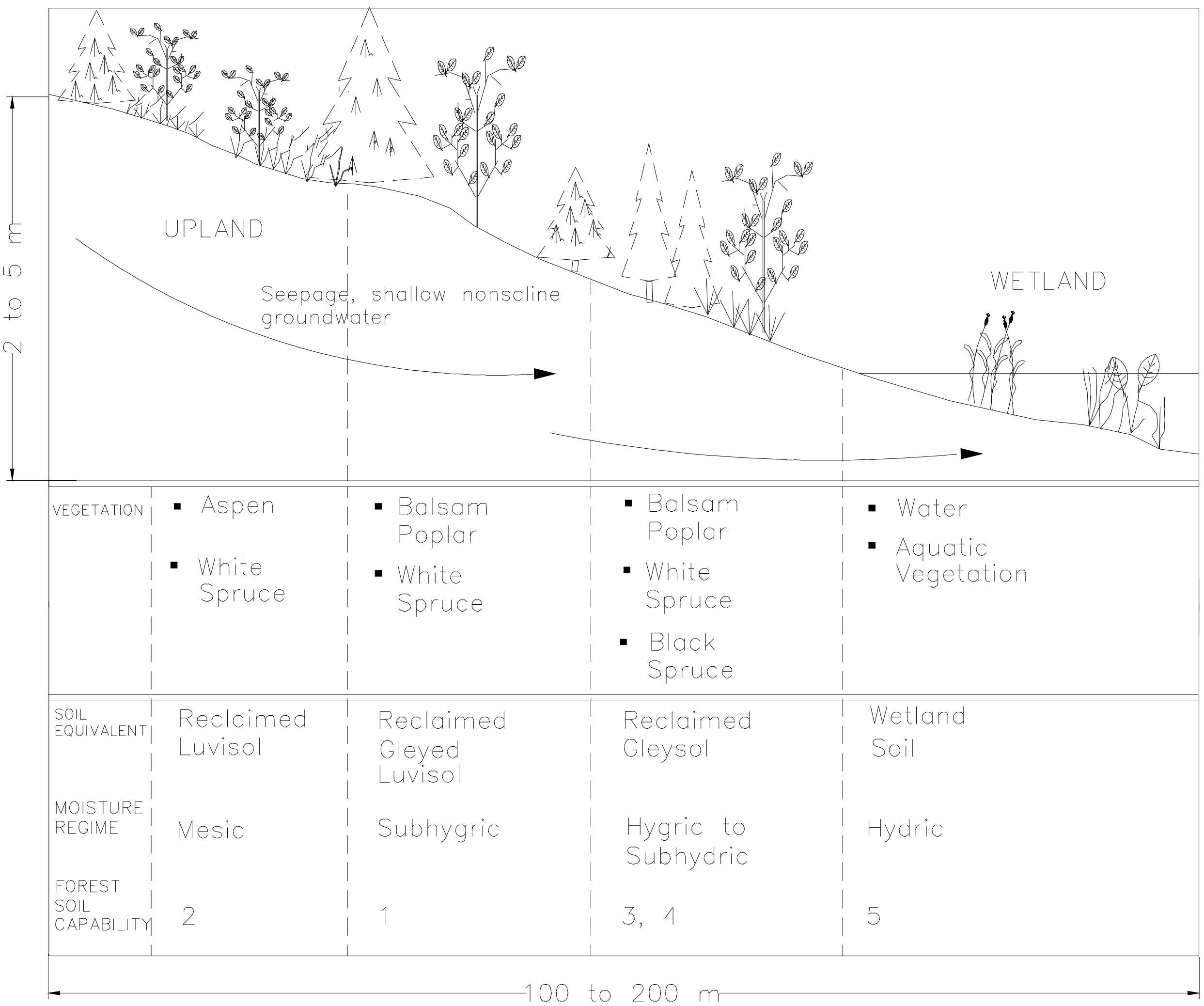
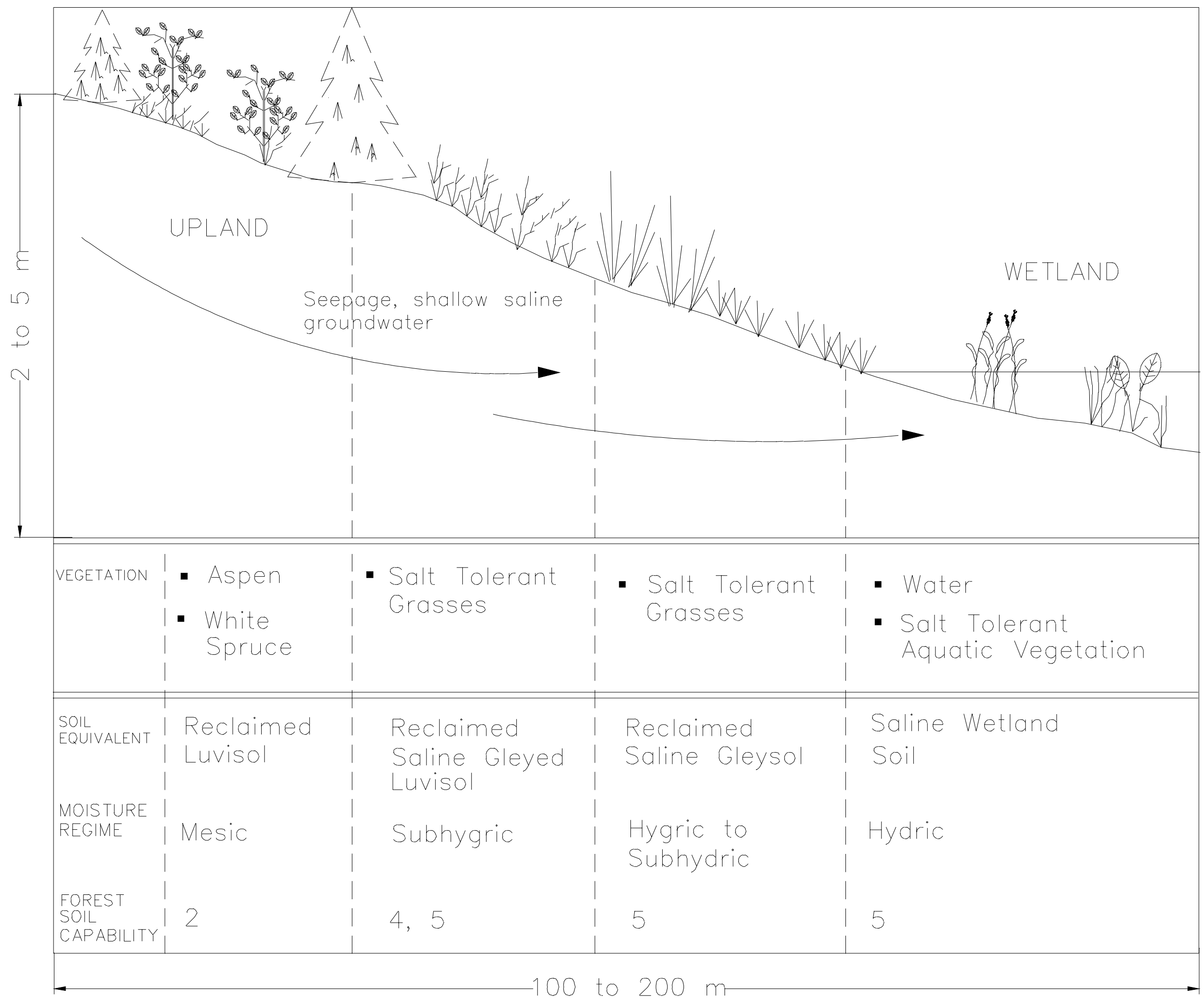


Figure D4. Expected Reclaimed Saline Soil – Vegetation Relationship for an Upland to Wetland Sequence



3. Vegetation Considerations For Wetland Creation

3.1 Define Target Wetland Type

The primary objective of revegetating wetlands is to develop a wetland community representative of a target wetland type. Although peatlands (bogs and fens) dominate the pre-development landscape in the oil sands region, the wetland types that can be created in the reclaimed landscape will resemble those of shallow or deep marsh wetland types. The potential wetland types in the reclaimed landscape are: 1) Altered, 2) Opportunistic; 3) Flood Control, 4) Water Treatment; 5) Habitat; 6) Vegetated Watercourses and 7) Littoral Zones. The selection of plants species used to revegetate wetlands will strongly depend on the target wetland type and it primary function.

3.2 Natural Recolonization

A major question regarding wetland creation is whether to enhance revegetation by transplanting desirable species or to simply allow natural invasion or recolonization from adjacent wetlands to occur. One of the significant findings of the comparison of created and natural wetlands in Oregon (Gwin and Kentula 1990) is that the composition of vegetation communities on the created wetlands was not notably different from those occurring on natural wetlands. However, significant differences occurred between the composition of vegetation communities on the created wetlands and the species included on the selected plant species list for those wetlands. Comparisons between the vegetation that occurred on created wetlands in Oregon with the planting lists in project plans indicated very few species in common. The percentage of all species found within the created wetland and on the corresponding planting list ranged from 0 to 7%. Therefore, 93 to 100% of the species in the created wetland were volunteers. This suggests that it may be unnecessary to plant wetland projects. However, before this inference can be made, one needs to determine if the species that volunteered on the projects also occurred in adjacent natural wetlands, or if the vegetation communities of the wetland projects consisted of mostly of inappropriate invasive or exotic species. Gwin and Kentula compared the species that occurred on the created wetlands with the species that occurred on natural wetlands and found that between 54 to 81 % of the species were common to both groups. These results suggest two things: 1) either the species included on the planting list was inappropriate for the wetland type or the geographical area, or 2) the planting list should include the volunteer species because these species also occurred in natural wetlands of the area.

In a Florida study (Gwin et al. 1991), similar results were reported, however, the analysis was taken one step further. In addition, to examining species composition, the relative abundance of each species was examined. For wetland projects that were planted, the percentage of the plant cover composed of species to be planted ranged from 0 to 33 %. The majority of the plant cover (48 to 93 %), as well as the number of species on the project was composed primarily of volunteer species.

Another study compared created wetlands revegetated by natural recolonization (i.e., simply flooded, soil was not disturbed) and natural wetlands. Galatowitsch and van der Valk (1996) found after three years of natural recolonization, natural wetlands had a mean of 46 species compared to 27 species for the restored wetlands. Restored wetlands had few shallow emergent species and more submersed aquatic species than natural wetlands. However, emergent species richness in restored wetlands was generally similar to natural wetlands. The seed banks of restored wetlands were not similar to natural wetlands. They contained fewer species and fewer seeds than those of natural wetlands. Galatowitsh and van der Valk suggest that one or more of the three sources of wetland propagules in the restored wetland (i.e., seed bank, seed from refugia population or propagules dispersed by waterfowl) was not operational for some species, at least in the short term.

These studies indicate that planting wetlands is not always necessary in wetland creation. Further research needs to be conducted to determine the best way to revegetation wetlands in the oil sands region.

3.3 Seeding and Transplanting Plant Materials

Transplanting wetland vegetation can be very time consuming and costly, and in some cases unnecessary. Kentula et al. (1992) listed several factors to consider on whether or not to enhance or accelerate revegetation by planting. The factors that contribute to the ability of a wetland to revegetate with appropriate wetland species include:

- surrounding land uses and their contributions to the project in terms of pollutants and undesirable seeds
- isolation of the entire project, or a portion of it, from other wetlands and appropriate seed sources
- vegetation strata, specifically whether herbaceous or woody species are targeted to colonize the wetland (e.g., herbaceous species volunteer and establish quite rapidly, and therefore may not require planting; woody species often take longer to establish and may require planting)
- time of year of construction takes place
- hydrology, specifically timing and duration of inundation, water level fluctuations and flushing of the site
- soil augmentation (such as organic soil or topsoil containing plant propagules taken from a wetland)

For instance, if a project is located downstream, adjacent to, or nearby an existing wetland, it is highly likely the project will have the ability to revegetate itself. Therefore, although the time required for a project to revegetate without planting may be longer than with planting, if conditions are correct, it may be appropriate to allow the project to revegetate naturally.

As previously discussed, soil salvaged from a donor wetland can accelerate revegetation by providing seeds and other propagules. Although propagules contained in soil removed from the donor wetland should germinate on the project, a direct correlation cannot be drawn between the vegetation present on the donor site and the species that germinate from the seed bank. Studies have shown that the species that germinate from the seed bank are often different from those present on the donor wetland (Weinhold and van der Valk 1988).

If the project is allowed to revegetate naturally, Kentula et al. (1992) suggest instituting a monitoring program within a year after construction to ensure that the project does revegetate with desirable species. He suggests the monitoring program need not consist of intensive sampling, but merely frequent routine checks to determine if the project is vegetated and what are the dominant species. If the project shows little sign of revegetating, if large areas of the site are being affected by erosion, if important components of the desired vegetation community are missing, or if many of the species are undesirable, a change in the revegetation plan is warranted and a planting scheme is required.

A study by Reinartz and Warne (1993) compared wetland vegetation in 11 naturally colonized sites to that in 5 wetlands to which 22 native species were introduced. They determined the diversity and richness of native species increase with wetland age, wetland size and with proximity to the nearest established wetland. They also determined wetlands seeded with native wetland species had a much higher diversity and richness of native wetland species than unseeded wetlands after two years. Seventeen of the 22 seeded species became established in at least two wetlands after simple introduction of seed to the site. As well, cattail cover after two years was lower in seeded sites. They concluded that the early introduction of a diversity of wetland plants might enhance the long term diversity of vegetation in created wetlands.

This area requires additional research in order to fully understand and demonstrate methods to create a marsh ecosystem. Another question not answered by the literature review is: are plant species effectively transferred by flowing water from connected wetlands. If this mechanism is effective, then perhaps only the upstream wetlands will required planting and downstream wetlands would be seeded naturally.

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APPENDIX E

FISH AND WILDLIFE CONSIDERATIONS FOR WETLAND CREATION

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TABLE OF CONTENTS

TABLES

APPENDICES

APPENDIX E: FISH AND WILDLIFE CONSIDERATIONS FOR WETLAND CREATION

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1. Wetland Design Criteria for Waterfowl

1.1 Overview

The annual life cycle of waterfowl can be broken down into distinct phases. Each phase of the life cycle can be defined by a key activity that the waterfowl are involved with. The phases of the life cycle are: spring migration, pair and territory establishment, nesting period, brood season, moulting period and fall migration. During each phase, waterfowl require wetland habitats. Some wetland types can provide habitat throughout the entire annual life cycle while other wetlands provide suitable habitat only during a specific portion of the year.

The potential wetland types in the reclaimed landscape are: 1) Altered, 2) Opportunistic; 3) Flood Control, 4) Water Treatment; 5) Habitat; 6) Vegetated Watercourses and 7) Littoral Zones. The different types of wetlands to be created in the reclaimed landscape will have different abilities to provide waterfowl habitat and, accordingly, will have different design considerations.

1.2 Spring Migration Habitat

Wetland Function: Spring migration habitat provides resting areas for waterfowl that are migrating through the study area to more northerly breeding grounds. As waterfowl are moving north as quickly as possible in order to reach their breeding grounds, the length of stay on spring migration habitat is of a much shorter duration than what might occur during the fall migration period.

Wetland Description: Typically, early spring migration habitat tends to be those shallow wetlands that first appear on the landscape as open water because of spring runoff (e.g., Opportunistic and Flood Control Wetlands). As the snow melts, it collects in low-lying areas and often provides open water prior to the permanent wetlands becoming ice-free. These shallow waters warm up quickly and food resources for waterfowl, such as invertebrates, become readily available. Waterfowl use these temporary wetlands for resting, feeding and courting. The size of these temporary wetlands obviously determines the number of staging waterfowl that can utilize any particular area at one time. Later spring migration habitat will be provided by the larger, permanent wetlands that become ice-free (e.g., Littoral Zones in lakes and many of the Constructed Wetlands). The littoral zone of lakes, such as Base Mine Lake, will be most valuable.

The large open areas beyond the littoral zone can also be important as resting areas for spring-migrating waterfowl.

Wetlands Working Group Equivalents: early spring staging habitat - Opportunistic and Flood Control Wetlands; late spring staging habitat – all Constructed Wetlands and Littoral Zone Wetlands.

Wetland Design: For the most part the early, temporary habitat should generally be less than 30 cm deep. For Opportunistic Wetlands, it is likely that the overall sizes will not be that large and therefore, their overall importance to migrant waterfowl may not be great. These Opportunistic Wetlands however, do provide some migration habitat and should be left in the landscape if other criteria for wetland suitability are met. It is possible that Flood Control Wetlands, flood attenuation wetlands, could be designed to provide a secondary function of spring staging habitat. If a wetland area is to be used for water storage during spring runoff, it would appear that the hydraulic retention time for these wetlands is such that it will provide some period of time where the wetland area would provide staging habitat. Water depths in the 30 cm range should be planned for and wetland areas greater than 10 acres have the potential for significant staging use. Hydraulic retention times should be designed to coincide with peak waterfowl and shorebird migration periods (late April to the end of May). Gradual drawdown through outflow and/or evaporation will prolong the availability of invertebrates to birds. Once ice-free, the littoral zones of large wetlands like Base Mine Lake will also provide valuable migration habitat.

Landscape Distribution: Opportunistic Wetlands providing spring migration habitat should be left throughout the landscape area as they opportunistically arise, especially those that are of a larger size. Spring migration habitat does not necessarily have to be associated with other wetland types and can function on its own.

Preferred Vegetation Communities: A range of wetland conditions from sparsely vegetated mudflats to moderately vegetated open shallows provide productive migration habitat. Grasses, sedges and low-lying forbs that are tolerant to some flooding are preferred vegetation communities for this wetland type. As these wetland areas generally have shallow water depths, very dense, tall vegetation, such as cattail and bullrush will for the most part make any shallow water unavailable to waterfowl. Vegetation is not necessarily essential and shallow water areas without any communities can provide spring migration habitat for waterfowl and a variety of other wetland-associated birds.

1.3 Spring Pair Habitat

Wetland Function: For most species of waterfowl, a breeding territory can incorporate a number of different wetland types. Wetlands, ranging from temporary roadside ditch water to large lakes, can all provide some component of a breeding territory. For the purposes of this document, spring pair habitat will refer to the ephemeral and temporary spring water that will occur throughout the landscape. Many of the comments made in the spring migration section with regards to wetland functions also apply here. The invertebrate populations that often bloom in these early wetlands are important food sources for hens that require protein rich diets for egg production. Additionally, these temporary wetlands provide additional pair space across the landscape. Given that waterfowl are very territorial at this time of year, additional wetland area helps to disperse waterfowl and increase the pair population within a landscape. The pair season is also much longer than the spring migration period. Different species arrive on the breeding grounds at different times during the spring. Mallards are the first to arrive with blue-winged teal and gadwall being the last to arrive.

Wetland Description: For the most part the description of the wetlands for spring migration habitat applies to this period as well. An important difference, however, is that while migration habitat tends to be larger in area, pair habitat can range in size from a few feet across to areas that are measured in acres. All can all provide valuable pair space. As the pair period is longer, ephemeral wetlands that hold water for a short period of time in very shallow depressions in the early spring to temporary wetlands that may hold some water throughout the summer during the wettest years, all provide pair habitat. Ephemeral wetlands are typically characterized by upland vegetation or wet meadow communities. The length of flooding is not long enough to modify the vegetation found in these basins. Temporary wetlands, however, may develop distinct wetland vegetation communities that are characterized by their ability to withstand dry periods later in the summer.

Wetlands Working Group Equivalents: Opportunistic Wetlands and Flood Control Wetlands.

Wetland Design: Shallow wetlands, with depths of 30 cm or less, can provide valuable pair space. The longer the wetlands retain standing water the more useful they are for a variety of species. Design criteria for spring migration habitat apply here as well. For any Flood Control Wetlands, or for that matter any other constructed wetlands that may be designed to be temporary, the hydrology and design calculations should try to maintain water in the basin until mid-May. The basin contour should be relatively flat and maintain a water depth of 30 cm or so across much of the area. Irregularities within the basin such as large rocks, small mounds of earth or clumps of vegetation can provide valuable loafing spots for the pairs utilizing the wetland. Placing rock can be accomplished during winter periods when they can be placed on the ice.

Landscape Distribution: The ideal distribution for pair habitat is to have it located in proximity to more permanent wetlands. Temporary wetlands that are located within 3.2 km of permanent wetlands can be important components of a territory. While Opportunistic Wetlands are not being specifically designed for, landform replacement practices that promote the development of these wetlands could be utilized around constructed and Littoral Zone Wetlands. There is no real maximum wetland density that should not be exceeded. In parkland and prairie biomes where pond densities are often greater than 70 ponds per square mile, ephemeral and temporary wetlands can often constitute a major portion of those wetlands.

1.4 Nesting and Brood Period

Wetland Function: The primary function of wetlands during this period is to provide some permanent wetland habitat through to the early September when the last of the late broods have fledged. Because these wetlands exist throughout this time period, these wetland habitats often provide a variety of other functions.

Wetland Description: Wetlands that retain standing water until mid-June can be classed as temporary, while wetlands lasting to late July can be classed as semi-permanent and those that last beyond August can be classed as permanent. During the first part of the year after the ice starts to melt, all these wetland types provide pair space. Convoluted shorelines and well-established emergent communities are two wetland characteristics that can increase the number of pairs utilizing a particular wetland. Both of these characteristics reduce sighting lines, which in turn helps to reduce intra-specific territorial conflicts. During the nesting period, permanently flooded emergent vegetation provides secure nesting habitat for overwater nesting species. Once waterfowl broods have hatched, permanent water provides the critical function of brood water, that is, wetland areas where broods feed and mature until they can fly. Temporary wetlands are also important to broods as well. Cox et al. (1998) has shown that duckling growth is positively related to invertebrate numbers. Temporary wetlands adjacent to permanent wetlands may be important feeding sites for hens and their broods as they can have high numbers of invertebrates. Aquatic vegetation within wetlands is not only important for providing escape cover from predators, it is critical in determining the abundance and diversity of invertebrate populations. The increased surface area provided by plant vegetation results in increased invertebrate populations over those wetlands which only have bare mineral substrates.

Wetland Working Group Equivalents: All permanent types of wetlands established on reclaimed landscapes can provide some value as breeding habitat, assuming other wetland criteria for wildlife are met.

Wetland Design: This section will deal primarily with wetlands constructed for habitat. On average natural wetlands in northern Alberta lose 25 to 30 cm of water due to evapotranspiration. Spring water depths between 60 and 100 cm in depth should ensure permanent water throughout the brood period. Water depths will influence the development of vegetation communities. The upper portion of the littoral zone should have a shallow slope to encourage the development of wet meadow vegetation. This is the zone that should shallowly flood during the spring (0 to 30 cm) and dry out as the summer progresses.

Emergent species, such as sedge, cattail and bullrush, all have different tolerances to water depths. At stable water depths of 50 cm, emergent stands comprised of these species begin to thin out. Open water zones of wetlands are generally indicative of water depths that are greater than 75 cm in depth. Beyond one meter, emergent growth generally does not occur. These open water zones, however, are generally dominated by submerged macrophytes. While some species, such as White-stemmed Pondweed, can grow in water as deep as 3 metres, most species are adapted to shallower depths (generally <1.5 m).

The littoral zone of natural, fish-bearing lakes in northeastern Alberta ranges between 10 to 30% of the total surface area. For waterfowl habitat, 100% of the wetland should be within the littoral zone, with the deepest zones having water depths of 1 to 1.5 metres. A variety of water depths promotes a diversity in plant communities and consequently an increase in overall biodiversity.

If permanent wetlands that are suitable as wildlife are limited in number in the landscape, then any habitat wetlands that are constructed should have a bowl shaped basin. A wetland of this shape will ensure that the succession of plant communities from wet meadow to open water will develop. If there is an opportunity to develop a variety of Habitat Wetlands, some wetlands should have flatter basins that average 45 to 60 cm in depth. These wetlands have the potential to develop into hemi-marshes, wetlands with half of their area being covered by emergent vegetation and the other half being open water. On all wetlands constructed for habitat purposes, convoluted shorelines should be developed. Nesting islands, nesting structures, loafing bars and other similar habitat improvement techniques can also be incorporated in the wetland design.

Littoral Zone wetlands areas can also provide important breeding wetlands, especially if submergent and emergent communities become established. Vegetated Watercourses also support some use by broods. Brood success on watercourses is dependent on how intermittent the stream is and its size. Broods on narrow watercourses are more susceptible to predation than on larger wetlands.

Water fluctuation capabilities can be an important habitat tool if active management is being proposed for some Habitat or Littoral Zone wetlands. Water level fluctuation capabilities are most important for Habitat Wetlands with shallow, flat basin profiles or Littoral Zone Wetlands with significant portions with water depths less than 75 cm. Drawdowns can be used to promote the establishment of emergent zones across a much larger area of the wetland. Most species require exposed mudflats for seed germination. For wetlands without water management capabilities, the amount of area exposed due to natural drawdowns will be the chief factor controlling the amount of emergent vegetation.

Landscape Distribution: Permanent brood habitat needs to be distributed throughout the reclaimed landscape. It is especially important that spring pair habitat and brood habitat occur in the same parts of the landscape. Having pair habitat located in areas where brood habitat does not exist will result in low brood survival rates. Pairs will be attracted to the temporary water, nest nearby and bring off a brood. If there is no permanent brood water within a reasonable distance, these broods will be susceptible to predation and other mortality.

Preferred Vegetation Communities: There is no single vegetation species or community that is preferred. Brood habitat should generally have emergent species such as cattail, bullrush or sedge as these species provide excellent escape cover for the broods. These species also provide suitable overwater nesting cover. The development of submergent communities within the wetland is also an important component of a successfully restored brood wetland. Submergents greatly increase the diversity of invertebrate populations that can occur in a wetland.

1.5 Moulting Period

Wetland Function: During mid to late summer, adult waterfowl undergo a moult to replace worn feathers. The females undergo their moult on the breeding habitat where they stay with their broods. Males typically undertake moult migrations to larger lakes where they can undergo their moults.

Wetland Description: Good brood habitat with well developed emergent zones that provide good escape cover also provides good moulting habitat for females. Males will likely leave the area, although littoral areas may be used if sufficient emergent habitat exists.

Wetland Working Group Equivalents: Habitat Wetlands (larger sizes) and Littoral Zones

Wetland Design: As detailed in the Nesting and Brood Period section.

Preferred Vegetation Communities: Emergent vegetation that provides good escape cover. Dense stands of sedge, cattail and bullrush all provide good moulting habitat. Flooded willow, both living and dead can also provide moulting habitat.

1.6 Fall Staging Period

Wetland Function: Waterfowl during the fall staging period will stop at large wetlands to feed and rest during their migration south. The fall staging period generally lasts from early September to freeze-up. Waterfowl may spend longer periods of time of staging habitat during the fall than time spent during the spring staging period.

Wetland Description: Generally, fall staging habitat is characterized by wetlands that are large and often have limited amounts of emergent habitat. Staging waterfowl will often form into large groups that will rest in the open water areas, sometimes at considerable distances from shore. Waterfowl remaining on the wetland to feed will require the same types of shallow littoral zones where invertebrate and macrophyte communities can develop. Sheltered bays are utilized during poor weather conditions. All constructed wetlands can provide staging habitat and their importance for this function will be directly related to their overall sizes.

Wetland Working Group Equivalents: Littoral Zones

Wetland Design: Littoral Zones of end pit lakes should be designed to promote the development of emergent and submergent communities in the littoral zone. In addition, large loafing bars, islands and other similar structures will be used by migrating waterfowl as resting areas. Not all of the shoreline needs to have established emergent communities. Sand or rock shorelines will also be used as resting areas by migrating waterfowl.

2. Wetland Design Considerations for the Enhancement of Fish and Wildlife Habitat

2.1 Overview

Wetlands are dynamic, highly productive ecosystems which, in association with surrounding uplands, provide valuable habitat for a diverse array of fish and wildlife species. The value of wetlands as habitat depends on factors including vegetation structure and diversity, surrounding land use, spatial dispersion, vertical and horizontal zonation and water chemistry (Westworth 1993). Westworth (1993) further evaluates the value of wetlands as fish and wildlife habitat. In summary, providing habitat for waterfowl and other wetland wildlife is one of the most important functions of Alberta wetlands supporting numerous species of birds, mammals, fish, amphibians and reptiles. Many other species that are not directly dependent on wetlands habitat utilize wetlands for feeding, nesting or cover. Finally, there is the food chain value of wetlands. Many other species of wildlife, including insectivorous birds and higher order predators, rely on organisms produced in wetlands as an important food resource.

Boreal wetlands provide a domestic environment for various kinds of wildlife. The marsh and shallow water complexes are by far the most significant wetlands in this respect (National Wetlands Working Group 1988). This review will attempt to evaluate habitat requirements for various fish and wildlife species assemblages and provide wetland design criteria, as appropriate, to enhance wildlife values. Although it is expected wildlife will utilize, to varying degrees, all wetland types on a reclaimed landscape recommendations will focus on Constructed Wetlands (Flood Control, Water Treatment and Habitat), Watercourse Wetlands and Lake Littoral Zone Wetlands. The wildlife enhancement of Water Treatment Wetlands and, to a lesser extent, Flood Control Wetlands is contingent on alleviating concerns related toxicity.

2.2 Fish

Lakes, streams and shallow seasonal/permanent wetlands are recognized as important habitats for fish with the latter providing important spawning and rearing habitat for species such as Northern Pike. Additionally, forage fish a such as brook stickleback and Cyprinids (minnows), an important food resource for other fish and wildlife species, find suitable habitat in shallow marshes and small permanent and ephemeral streams. In the reclamation of wetlands the potential exists to create habitats in lake littoral zones, watercourses and marshes which provide good spawning, rearing, feeding and overwintering areas for sport and forage fish. Design considerations are provided (L. Rhude, pers. comm.) below.

2.2.1 Lake Littoral Zones

Design considerations for providing fish habitat in littoral zones include:

i. Littoral zone should comprise at least 20% of the lake area with a water depth of less than 3 metres.

ii. Littoral zone should gradually increase in depth to compensate for fluctuating water levels.

iii. Irregular shorelines with the development of shallow bays, shoals and islands should be provided to increase habitat edge and variety.

iv. Iirregular bottom contours with underwater structures including reefs, etc. should be provided, as well as the establishment of rooted and floating vegetation.

v. A diversity of quiet water and wave susceptible areas should be created.

2.2.2 Watercourses and Flood Control Wetlands

Design considerations for providing fish habitat in flood control wetlands include:

i. The lower reach of streams should be underdesigned to allow flooding during high water events.
ii. The gradient in water courses should be such to allow fish to travel from the lake into the stream (no barriers).
iii. Flooded areas should be designed to ensure that as water recedes fish would not get trapped (i.e. no berms).
iv. The development to sedges, wet meadow grasses and emergent aquatic macrophytes (i.e. cattails, bulrushes) should be promoted.
v. Watercourses should vary in shape and sinuosity with shoreline irregularities (e.g., inland projections, etc.) developed in channels and marshes to enhance habitat diversity.
vi. Pools (greater than 1 meter in depth) should be created to provide overwintering habitat.
vii. Cover should be provided in the form of woody debris, undercut banks, etc.

2.3 Wildlife

The Eastern Boreal Forest Region supports a large diversity of wildlife species including at least 236 species of birds and 43 species of mammals (Westworth 1990). Wildlife species utilize a diversity of wetland types and associated terrestrial environments to satisfy basic habitat requirements related to food, cover and reproduction. Many wetlands types with specific habitat attributes may be required during the annual life cycle of many species. Notably, waterfowl utilize a diversity of habitat types ranging from temporary, shallowly flooded wetlands to large lakes for migration, breeding, brood rearing and moulting. Similarly, migrant and breeding shorebirds will opportunistically utilize a variety of boreal wetland types.

Comprehensive studies documenting the aquatic habitat requirements of wildlife in the Central Mixedwood Natural Subregion do not appear to exist for many species. Golder (1997) documented the potential and observed use of vegetation communities, including open water, marsh, gramminoid/shrubby fen, wooded fen/bog and riparian habitats, by bird, mammal, amphibian and reptile species on Shell Canada Ltd.'s Lease 13 (*Report on Wildlife Baseline Conditions for Shell's Proposed Muskeg River Mine Project*). Information provided by Golder (1997) for wetland habitats is presented in Tables 1, 2 and 3 in Appendix E1.

Wildlife habitat requirements and associated design considerations for wetland types on a reclaimed landscape will need to be provided based on available information. Because it is not possible to consider all species, Habitat Suitability Index (HSI) information available for aquatic wildlife species, including semi-aquatic furbearers and waterfowl will need to be utilized to develop design criteria which will optimistically benefit a broad range of wetland related wildlife. Also, it is reasonable to assume that wetland design considerations for waterfowl (see Section 1) are consistent with those for a broad range of other wildlife species. Ultimately, the wildlife value and utilization of wetlands in reclaimed landscapes will be dependent on the diversity, distribution, abundance and productivity of the aquatic and terrestrial ecosystems which evolve over time.

2.3.1 Opportunistic

Wildlife utilization of wetlands which develop opportunistically throughout the landscape will be highly variable and largely dependent on factors including basin morphometry, water quality, hydrology, substrate and vegetation communities. Retention of these wetlands in the reclaimed landscape is recommended, where possible, to enhance habitat diversity and distribution.

2.3.2 Constructed Wetlands

2.3.2.1 Flood Control

Wetlands designed for flood control/attenuation have the potential to provide critical spring migration habitat for waterfowl and shorebirds. Shallow water depths are requisite to optimizing utilization. Migratory shorebirds and waterfowl use habitats of variable depth, vegetation height and density which harbour rich invertebrate food resources.

Design considerations for providing wildlife habitat in flood control wetlands include:

- i. Wetlands should be designed to promote extensive shallow flooding (30 cm or less) over relatively large areas. Water depths for foraging shorebirds range from 0 cm (mudflat) to 18 cm. Waterfowl can utilize areas of greater water depth.
- ii. Hydraulic retention time should be designed to coincide with peak waterfowl and shorebird migration periods (late April to the end of May).
- iii. A range of wetland conditions ranging from sparsely vegetated mudflats to moderately vegetated open shallows provide productive migration habitat. Flood tolerant grasses, sedges and forbs will optimistically establish over time given favorable growing conditions.
- iv. Gradual drawdown through outflow and/or evaporation will prolong the availability of invertebrates to birds foraging in shallow water and mudflats.

2.3.2.2 Habitat

Wetlands designed and constructed to function primarily as wildlife habitat are anticipated to develop into semi-permanent and permanent marshes. These areas have the potential to support a relatively high diversity and abundance of wildlife species if aquatic and terrestrial environments are favorable. Historically, semi-aquatic furbearers (beaver,muskrat, river otters, mink) and ducks (dabbler and diver species) have been selected as the representative target species for aquatic habitats.

Design considerations for wetlands with a primary function of providing wildlife habitat include:

i. Gently sloping basin and shoreline contours creating a bowl shaped basin will promote the establishment of open water, deep marsh, shallow marsh and wet meadow zones.

ii. Extensive littoral zones (generally <1.5 metres) with some areas of deeper water provide overwintering habitat for semi-aquatic furbearers (primarily muskrat) and forage fish. Bottom contours should include local irregularities to increase the interspersion of shoreline and shallow and open water areas (Green and Salter 1987).

iii. Convoluted shorelines, bays, peninsulas, shoals and islands increase habitat edge and provide a variety of habitats for wildlife (Green and Salter 1987).

iv. Wetland substrates should be relatively impervious and the transplanting of soil and substrates from existing wetlands should be undertaken to accelerate the establishment of aquatic macrophytes. The development of diverse and robust emergent, submergent and floating aquatic vegetation is critical to maximizing wildlife habitat values.

v. Relatively stable water levels are required to maintain muskrat and beaver populations.

vi. Vegetation communities dominated by deciduous shrub and tree species should be established in riparian and upland areas adjacent to wetland habitats being developed as beaver habitat.

2.3.2.3 Water Treatment Wetlands

As noted in the overview on design considerations, the provision of wildlife enhancement features in water treatment wetlands is contingent on the alleviation of toxicity concerns. Depending on the specifics for a particular water treatment wetland (e.g., types of contaminants, rate of toxicity attenuation over time) there will need to be a decision whether to include habitat features in the initial design and construction or defer them to a later date when the role of the wetland as a treatment system has declined or ceased.

2.3.3 Vegetated Watercourses

Searing (1979) states that streams are widely used and are probably the most important water bodies for semi-aquatic furbearer populations. Semi-aquatic mammals (beavers, muskrats, mink and river otters) are largely associated with riparian habitats which are maintained by the action of streams and lakes as secondary series or subclimax communities with a considerable edge effect. Riparian areas are wetlands associated with running water systems found along rivers, streams and drainageways (Golder 1998a). In addition to other wildlife values, riparian areas provide important habitats for breeding birds. Species richness and diversity was greatest in the dogwood-balsam poplar-aspen poplar (e1) stand, a riparian community type in the Suncor Millennium LSA (Golder 1998b). Watercourses and associated riparian areas have the potential to provide valuable food resources (browse species) and critical travel corridors for moose and other ungulates within a reclaimed landscape. Their value as travel corridors is contingent on their integration with existing natural travel corridors (river valleys, etc) in the area.

Design considerations for providing wildlife habitat in vegetated watercourses include:

i. Water course construction or enhancement for wildlife should involve three components (Green and Salter 1987): 1) water course location and design, 2) channel and streambank stabilization, and 3) streambank enhancement.

ii. For maximum use by wildlife, a watercourse should have a shallow gradient (less then 11%) and a sinuous channel to slow water velocities. Sinuous channels eventually provide a variety of bank heights and shapes through natural erosion processes. Pools can be constructed at bends to provide deep areas for fish and aquatic mammals. In flatland areas, bends in the watercourse can be extended to create oxbow lakes and wetlands (Green and Salter 1987).

iii. Streams developed for beaver habitat should have low stream gradient (<15%), narrow width (<5m), located in U-shaped valleys, distinct channel morphology allowing the establishment of pools behind dams, banks with less than 45° slope, bank height of less than 2 meter and bank material consisting of clay soils (Bovar 1997).

iv. The establishment of vegetation along stream banks (sedges, grasses, bulrushes, cattails, etc.) provides bank stabilization, food and cover for wildlife and, through shading, moderates water temperatures (Green and Salter 1987).

v. In establishing riparian vegetation communities, plantings of preferred ungulate browse species, including red osier dogwood, saskatoon, choke cherry, and willow should be undertaken in addition to balsam poplar, alder, etc. to enhance habitat value and wildlife utilization of these areas.

vi. In establishing and revegetating riparian zones, soil replacement should be undertaken to the water's edge to promote rapid and successful establishment of vegetation.

2.3.4 Littoral Zones

Many of the design criteria previously provided for the lake littoral zone for fish habitat are consistent with those for wildlife species. Design considerations include:

i. Littoral zone should comprise a minimum of 20% of the lake area with a water depth less than 3 metres.

ii. Bottom contours should be irregular to provide a variety of bottom types. Narrow to wide shoreline shelves with gradual slopes (11-22%) and average depths of 0.5-1.5 metres encourage the growth of aquatic plants. In deep water areas and along some parts of the shoreline, steeper slopes (44-67%), should be used to provide access to deep water and limit plant growth (Green and Salter 1987).

iii. Irregular shorelines with the development of shallow bays have the potential to develop into marsh habitats.

iv. The development of a variety of shoreline characteristics sholuld be provided, ranging from emergent vegetation communities (waterfowl cover, nesting sites) to having mudflats, gravel bars (shorebird foraging, nesting sites).

v. Islands should be provided that are suitable for use by waterfowl as well as colonial birds (American white pelican, double-crested cormorant, common tern, etc). Design criteria for the creation of nesting islands for colonial birds can be found in *Multi-Species Habitat Enhancement Techniques* (Ewashcuk and Gurr 1992).

vi. Elevated nesting platforms should be provided for osprey and bald eagles.

2.4 Monitoring

Wetland design criteria and adaptive management will be employed in the progressive development of a variety of wetland types in reclamation landscapes. Ultimately, the final product will be largely determined by complex natural processes. In evaluating the relative success in providing viable productive habitats which will support a diversity of wildlife species, it is imperative that an ongoing monitoring protocol be established. Consistent with recommendations provided in *Guidelines For Reclamation To Forest Vegetation in the Alberta Oil Sands Region* (Oil Sands Vegetation Reclamation Committee 1998) a combined course filter-fine filter target approach is recommended to evaluate the re-establishment of aquatic plant communities and document whether the biophysical habitat requirements of several aquatic wildlife species are being provided in the reclaimed landscape.

3. Breeding Bird Densities For Non-Waterfowl Species Utilizing Wetland Habitats

Table E1 provides data that can be used to monitor and assess reclaimed wetland habitats. The breeding bird densities will provide a basis of comparison between species use of native habitats and those observed on reclaimed oil sands landscapes. In using this data, it must be recognized that variability in population densities in the same habitat will commonly occur from year-to-year. These temporal variations are due to factors such as weather patterns, habitat conditions on the wintering grounds and other population influencing effects which can increase or decrease returning breeding populations for a given habitat. These are not absolute densities but rather, they are indicators of habitat suitability.

Table E1. Breeding Bird Densities of Native Habitat s in the Oil Sands Region

SPECIES	DENSITY	HABITAT TYPE
Sora	68 territories/100ha	sedge fen
Greater Yellowlegs	11 territories/100ha	sedge fen
Lesser Yellowlegs	3 territories/100ha	open bog
Common Snipe	4 territories/100ha	tall bottomland willow
	12 territories/100ha	shrub fen
Alder Flycatcher	12 territories/100ha	tall bottomland willow
	18 territories/100ha	shrub fen
Least Flycatcher	4 territories/100ha	tall bottomland willow
Marsh Wren	247 territories/100ha	Phragmites marsh
Black-and-white Warbler	28 territories/100ha	tall bottomland willow
Tennessee Warbler	49 territories/100ha	tall bottomland willow
Yellow Warbler	5 territories/100ha	tall bottomland willow
	2 territories/100ha	shrub fen
Northern Waterthrush	9 territories/100ha	tall bottomland willow
Common Yellowthroat	5 territories/100ha	sedge fen
	99 territories/100ha	willow dominated fen
	72 territories/100ha	swamp birch dominated fen
	25 territories/100ha	whitetop meadow
Wilson's Warbler	4 territories/100ha	tall bottomland willow
	69 territories/100ha	willow-dominated fen
American Redstart	56 territories/100ha	tall bottomland willow
Yellow-headed Blackbird	617 territories/100ha	Phragmites marsh
Red-winged Blackbird	192 territories/100ha	sedge fen
Common Grackle	39 territories/100ha	sedge fen
Savannah Sparrow	80 territories/100ha	whitetop meadow
LeConte's Sparrow	4 territories/100ha	tall bottomland willow
	17 territories/100ha	shrub fen
	25 territories/100ha	shrubby marsh
Clay-coloured Sparrow	72 territories/100ha	shrub fen
	39 territories/100ha	whitetop meadow
White-throated Sparrow	65 territories/100ha	tall bottomland willow
	2 territories/100ha	shrub fen
Fox Sparrow	46 territories/100ha	tall bottomland willow
Lincoln's Sparrow	35 territories/100ha	shrub fen
	21 territories/100ha	sedge fen
	7 territories/100ha	tall bottomland willow
Swamp Sparrow	11 territories/100ha	tall bottomland willow
	88 territories/100ha	shrub fen
	237 territories/100ha	willow dominated sedge fen
	94 territories/100ha	shrubby marsh
Song Sparrow	11 territories/100ha	tall bottomland willow
	46 territories/100ha	Phragmites marsh

Sources: Erskine (1976) and Francis and Lumbis (1980)

4. Observed Waterfowl Densities For Northern Alberta Wetlands

The data presented in this section can be used in the monitoring and performance assessment of reclaimed wetland habitats. The waterfowl data presented in the following tables provide a basis to compare species use of natural wetland habitats with that observed on reclaimed wetland habitat in oil sands landscapes.

Table E2. Pair Densities, Brood Densities and Species Composition in Natural Wetlands

Northeastern Alberta:

A) Pair densities observed on natural wetlands.

Wetland Edge	Dabbler prs/mile	Diver prs/mile	Total prs/mile
Lakes:			
Cattail	16.6	15.4	32.0
Sedge	8.6	9.0	17.6
Sedge/shrub	10.6	7.7	18.3
Flooded shrub	14.0	4.8	18.8
Sedge, sedge-shrub, Flooded shrub	10.9	7.3	18.2
Wooded edge	4.0	4.0	8.0
Streams:			
Mostly sedge, some wooded	9.2	10.0	19.2
Wooded edge	15.4	6.3	21.7

B) Brood densities observed on natural wetlands.

Wetland Edge	Dabbler brs/mile	Diver brs/mile	Total brs/mile
Lakes:			
Cattail	1.8	3.4	5.2
Sedge	0.4	5.8	6.2
Sedge/shrub	0.9	2.8	3.7
Flooded shrub	0	1.0	1.0
Sedge, sedge-shrub, Flooded shrub	0.6	4.5	5.1
Wooded edge	0.5	2.2	2.7

Source: Donaghey (1974)

C) Species composition of waterfowl observed on natural wetlands in the Oil Sands area.

Species	Percent composition 1976 (1977)
Dabblers	
Mallard	13.3 (6.4)
Wigeon	5.0 (.03)
Green-winged teal	3.0 (0.7)
Blue-winged teal	2.3 (0.9)
Shoveler	2.1 (1.1)
Pintail	0.8 (0.6)
Gadwall	0.3 (0.4)
Unidentified dabblers	2.2 (4.9)
Total dabblers	29.0 (15.0)
Divers	
Scaup	32.7 (9.5)
Ringneck	14.2 (3.0)
Bufflehead	7.4 (4.4)
Goldeneye	3.5 (3.2)
Merganser	0.7 (0.5)
Canvasback	0.4 (0.2)
Redhead	0.2 (0.2)
Ruddy	0.2 (0.1)
Unidentified divers	7.3 (17.9)
Total divers	66.6 (39.0)
Unidentified Ducks	4.5 (46.0)

Source: Hennan and Munson (1979)

Northwestern Alberta:

Mean density of breeding pairs – 3.3 pairs/ha
Mean density of broods – 1.7 broods/ha
Total Dabbler broods – 66%
Total Diver broods – 34%

Source: Sankowksi and Joynt (1992)

5. Artificial Nesting And Habitat Structures

Nesting Islands for Ducks: In general, the use of islands by nesting ducks is negatively correlated with potential upland nesting cover. Therefore, the justification for constructing islands should include an evaluation of upland cover types and areas, as well as the wetland's brood-use potential. In reclaimed landscapes where the uplands are to be returned to various cover types which approximate existing native habitats, there should not be a lack of upland nesting cover. Islands may be a useful tool where wetlands may be restored prior to significant upland reclamation having been completed.

There are two types of earth islands that can be constructed. Large islands, that have a flat top surface area of 10m by 25m and 5:1 side slopes, are generally constructed in large wetlands, for example the littoral zone of end pit lakes. They should be located 100 m offshore and constructed in water varying in depth from 30 to 100cm. These islands should be revegetated with various species of grass, forbs and shrubs such as snowberry or willow. Islands such as these provide other functions for waterfowl. Islands constructed in littoral zones areas are likely to receive heavy loafing use by not only breeding waterfowl but also migrants during spring and fall migrations. Islands in larger littoral zones should be constructed in those areas that are sheltered from the prevailing winds. Islands in erosion prone locations may have to be armored with rock. Another alternative for preventing erosion is to promote the growth of fibrous rooted vegetation on the windward side of the island.

Small earth mounds are more appropriate for the constructed wetlands (for flood control ,water treatment, or habitat) being created in the reclaimed landscapes. These are generally small mounds of earth that have a 2m diameter flat top. These mounds should be placed in those portions of the wetland that will have water throughout the breeding season. When available, rock can be used to create small nesting islands. Rock can be dumped on the ice in sufficient quantities to create a rock mound. In addition, a load of soil should be dumped on top in order to provide a substrate for vegetation to grow in. The rock will settle to the bottom during the spring thaw.

For large and small islands there are certain design and construction criteria that are common to both. They are as follows:

i. Both should have a freeboard of .9m above the spring water level.
ii. Islands should be constructed with good clay type of soils that can withstand wave action.
iii. Islands should be constructed with a moat around their perimeter. This helps to deter access by non-avian predators.

Artificial Nesting Structures: This category of nesting structure includes nesting rafts, boxes and baskets. One of the most significant aspects to be considered when placing these types of nesting structures is the issue of long-term management. These structures require on-going maintenance such as the replacement of nesting material or the removal of old materials. Various references are available on the design and construction of these nesting structures.

Loafing Spots: Pairs, broods, moulting and migrant waterfowl all make use of loafing spots. For littoral zones, large loafing structures such as rock islands can be used. In constructed wetlands (for flood control, water treatment or habitat) loafing spots can be created by placing a variety of structures in the wetland. Large rocks, logs or tree stumps placed along the edge of the wetland can provide important loafing areas for waterfowl. Offshore, logs can be anchored in open water areas to provide suitable loafing areas.

6. Artificial habitat structures for fish

The most common natural cover is rooted aquatic plants growing in the littoral zones of lakes and wetlands. The amount of natural cover will be one of the factors determining the carrying capacity of a waterbody. Artificial reefs or fish shelters in lakes can increase the carrying capacity by providing a base on which minute plant and animals forms can attach themselves. This aquatic life provides the are the basis for a food chain which can support fish. Artificial reefs also provide protective cover for fish.

In deciding when and where to place artificial structures, the following points should be considered:

i. Consider which areas lack natural shelter structures or spawning materials.
ii. Consider which fish species are involved and their requirements.
iii. Determine the type of bottom substrate (should be firm enough to support the reef).
iv. Consider the seasonal fluctuation in water levels in the particular wetland.

Artificial reefs can be constructed from a broad range of materials. Materials such as auto bodies, parts and tires are not recommended. The following materials can be used to create artificial reefs:

i. Rock, concrete, broken tile: Reefs constructed out of this material will serve as spawning substrate as well as a shelter for forage fish and game fish juveniles. The material is stacked in a loose pile in 2 to 5 metres of water. The height of the pile can be variable; however, allowances should be made for settling so that a metre or more of material protrudes above the wetland bottom.
ii. Bundled brush structures: Bundles of brush are bound together with synthetic rope and ballast is attached to the bundle. This is placed on the ice and allowed to sink to the bottom at spring break-up.
iii. Stacked brush frame: A 1.5 by 3 metre frame of lumber, logs or poles is constructed. Brush is stacked to a height of about 2 metres on top of the frame and fastened securely with No. 9 galvanized wire or light steel cable. Ballast is fastened to the frame and placed on the ice.

iv. Christmas Tree Unit: This habitat unit is made by drilling a 10mm hole in the butt of a conifer and inserting a steel bar 30 cm long in the hole. The butt is then placed in a 5 gallon can which is then filled approximately three quarters full with concrete. The unit is placed in an area of the wetland which has a flat bottom. Three or more of these units should be strapped together at one location to prevent tipping. Avoid using discarded Christmas trees which may have toxic substances such as artificial snow or tinsel.

v. Tree Stumps: Tree stumps from recently cleared land can provide cover that is suitable for both large and small fish. When thoroughly waterlogged they will last for many years. The stumps should be weighted so that the roots will be uppermost after the structure has sunk. Stumps can be put out in groups or singly depending on the area of cover required. Stumps can be placed by boat or left on the ice.

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APPENDIX E1

POTENTIAL AND OBSERVED USE OF VEGETATION COMMUNITIES BY BIRDS, MAMMALS AND AMPHIBIAN AND REPTILE SPECIES IN THE SHELL LEASE 13 LOCAL STUDY AREA

APPENDIX E1 POTENTIAL AND OBSERVED USE OF VEGETATION COMMUNITIES BY BIRDS, MAMMALS AND AMPHIBIAN AND REPTILE SPECIES IN THE SHELL LEASE 13 LOCAL STUDY AREA

Table 1. Potential and Observed Use of Vegetation Communities by Bird Species in the Shell Lease 13 Local Study Area (Golder 1997)

Common Name	Open Water	Graminoid or Shrubby Fen	Riparian	Marsh	Wooded Fen/Bog
Red-throated Loon	X				
Arctic Loon	X				
Common Loon	X		P		
Pied-Billed Grebe	X		P	X	
Horned Grebe	X		P	X	P
Red-necked Grebe	X		P	X	
Eared Grebe	X			X	
Western Grebe	X				
American White Pelican	X		P		
Double-crested Cormorant	X		P	X	
American Bittern		X	P	X	P
Great Blue Heron	X	X	P	X	
Great Egret	X	X		X	
Tundra Swan	X				
Trumpeter Swan	X				
Goose	X				
Snow Goose	X				
Ross' Goose	X				
Canada Goose	X		P		P
Wood Duck	X	X		X	
Green-winged Teal	X	X	P	X	P
American Black Duck	X	X		X	
Mallard	X	X	P	X	P
Northern Pintail	X	X	P	X	P
Blue-winged Teal	X	X	P	X	P
Cinnamon Teal	X	X		X	
Northern Shoveler	X	X	P	X	P
Gadwall	X	X	P	X	P
Eurasian Wigeon	X	X		X	
American Wigeon	X	X	P	X	P
Canvasback	X	X	P	X	P
Redhead	X	X	P	X	P
Ring-necked Duck	X	X	P	X	P
Greater Scaup	X	X		X	
Lesser Scaup	X	X	P	X	P
Harlequin Duck					
Oldsquaw	X				
Surf Scoter	X	X		X	
White-winged Scoter	X	X		X	
Commom Goldeneye	X	X	P	X	
Barrow's Goldeneye	X	X		X	
Bufflehead	X	X	P	X	
Hooded Merganser	X	X	P	X	P
Common Merganser	X	X	P	X	

Common Name	Open Water	Graminoid or Shrubby Fen	Riparian	Marsh	Wooded Fen/Bog
Red-breasted Merganser	X	X	P	X	
Ruddy Duck	X		P	X	P
Osprey	X		P		
Bald Eagle	X		P		
Northern Harrier		X	P	X	P
Sharp-skinned Hawk					X
Cooper's Hawk					
Northern Goshawk					
Broad-winged Hawk					P
Swainson's Hawk					
Red-tailed Hawk					
Rough-legged Hawk					
American Kestrel					
Merlin					
Peregrine Falcon	X		P	X	P
Gyrfalcon					
Spruce Grouse					
Willow Ptarmigan					P
Ruffed Grouse					
Sharp-tailed Grouse			P		P
Sora		X	P	X	P
American Coot	X	X	P	X	P
Sandhill Crane		X	P	X	P
Whooping Crane					
Black-bellied Plover					
Lesser Golden Plover					
Semipalmated Plover					
Killdeer			P		
American Avocet	X			X	
Greater Yellowlegs		X		X	P
Lesser Yellowlegs		X		X	P
Solitary Sandpiper		X	P	X	P
Willet				X	
Spotted Sandpiper			P	X	X
Upland Sandpiper					
Whimbrel					
Hudsonian Godwit					
Marbled Godwit			P		P
Ruddy Turnstone					
Sanderling					
Semipalmated Sandpiper					
Western Sandpiper					
Least Sandpiper			P		P
White-rumped Sandpiper					
Baird's Sandpiper					
Pectoral Sandpiper					
Dunlin					
Stilt Sandpiper					
Buff-breasted Sandpiper					
Short-billed Dowitcher					P
Long-billed Dowitcher					

Common Name	Open Water	Graminoid or Shrubby Fen	Riparian	Marsh	Wooded Fen/Bog
Common Snipe		X		X	P
Wilson's Phalarope	X	X	P	X	P
Red-necked Phalarope	X	X		X	
Red Phalarope	X	X		X	
Franklin's Gull	X	X	P	X	P
Bonaparte's Gull	X	X	P	X	P
Mew Gull	X		P	X	
Ring-billed Gull	X		P	X	
California Gull	X		P	X	
Herring Gull	X		P	X	
Iceland Gull	X			X	
Glaucous Gull	X			X	
Caspian Tern	X				
Common Tern	X	X	P	X	P
Arctic Tern	X			X	
Black Tern	X	X	P	X	P
Rock Dove					
Mourning Dove					
Great-horned Owl			P		P
Snowy Owl					
Northern Hawk Owl		X			P
Barred Owl					
Great Gray Owl		X	P		P
Long-eared Owl					
Short-eared Owl		X		X	
Boreal Owl					P
Common Nighthawk					
Belted Kingfisher		X	P	X	P
Yellow-bellied Sapsucker					
Downy Woodpecker					
Hairy Woodpecker					
Three-toed Woodpecker					X
Black-backed Woodpecker					X
Northern Flicker					
Pileated Woodpecker					
Olive-sided Flycatcher		X	P		P
Great-crested Flycatcher					
Western Wood-Pewee		X	P	X	P
Yellow-bellied Flycatcher					X
Alder Flycatcher			P		X
Least Flycatcher					X
Eastern Phoebe		X	P		P
Say's Phoebe			P		
Eastern Kingbird		X	P		P
Horned Lark					
Tree Swallow		X	P	X	P
Bank Swallow			P	X	
Cliff Swallow			P	X	
Barn Swallow			P	X	
Gray Jay					X
Blue Jay					

Common Name	Open Water	Graminoid or Shrubby Fen	Riparian	Marsh	Wooded Fen/Bog
Black-billed Magpie			P		
American Crow					P
Common Ravern			P		P
Black-capped Chickadee					
Boreal Chickadee			P		X
Red-breasted Nuthatch					X
Brown Creeper					
House Wren					
Winter Wren					
Marsh Wren		X	P	X	P
Golden-crowned Kinglet					
Ruby-crowned Kinglet					X
Mountain Bluebird					P
Veery					
Gray-cheeked Thrush					
Swainson's Thrush			P		X
Hermit Thrush					X
American Robin			P		
Northern Mockingbird					
Brown Thrasher					
American Pipit					P
Bohemian Waxwing			P		
Cedar Waxwing			P		X
Northern Shrike					
European Starling					
Solitary Vireo					
Warbling Vireo					
Philadelphia Vireo					X
Red-eyed Vireo			P		
Tennessee Warbler		X	P	X	P
Orange-crowned Warbler			P		X
Yellow Warbler		X	P		X
Magnolia Warbler			P		X
Cape May Warbler					
Yellow-rumped Warbler					X
Warbler					
Palm Warbler		X		X	
Bay-breasted Warbler					P
Blackpoll Warbler					X
Black-and-White Warbler			P		P
American Redstart			P		X
Ovenbird					X
Northern Waterthrush		X	P	X	P
Connecticut Warbler					X
Mourning Warbler					
Common Yellowthroat		X	P	X	P
Wilson's Warbler			P		P
Canada Warbler			P		P
Western Tanager					X
Rose-breasted Grosbeak					
Indigo Bunting					

Common Name	Open Water	Graminoid or Shrubby Fen	Riparian	Marsh	Wooded Fen/Bog
American Tree Sparrow			P		P
Chipping Sparrow					X
Clay-colored Sparrow		X	P		P
Vesper Sparrow					P
Savannah Sparrow		X		X	P
LeConte's Sparrow		X		X	X
Sharp-tailed Sparrow		X	P	X	P
Fox Sparrow			P		P
Song Sparrow		X	P	X	P
Lincoln's Sparrow		X	P	X	P
Swamp Sparrow		X	P	X	P
White-throated Sparrow			P		X
White-crowned Sparrow			P		P
Harris' Sparrow					
Dark-eyed Junco					X
Lapland Longspur					
Smith's Longspur					
Snow Bunting					
Bobolink					
Red-winged Blackbird		X	P	X	P
Western Meadowlark					
Yellow-headed Blackbird		X	P	X	P
Rusty Blackbird		X	P		P
Brewer's Blackbird		X	P		P
Common Grackle		X	P		P
Brown-headed Cowbird		X			
Northern Oriole					
Pine Grosbeak					
Purple Finch					
Red Crossbil					
White-winged Crossbill					X
Common Redpoll					P
Hoary Repoll					
Pine Siskin					X
American Goldfinch					X
Evening Grosbeak					
House Sparrow					
Species Richness	63	70	97	78	112
Richness Index	0.23	0.34	0.77	0.47	1.00

X indicates species observed on Lease 13 Local Study Area
P indicates species potentially on Lease 13 Local Study Area

Table 2. Potential and Observed Use of Vegetation Communities by Mammal Species in the Shell Lease 13 Local Study Area (Golder 1997)

Common Name	Open Water	Graminoid or Shrubby Fen	Riparian	Marsh	Wooded Fen/Bog
Masked Shrew					X
Dusky Shrew			P		P
Water Shrew		P	P	X	
Arctic Shrew					P
Pygmy Shrew					P
Little Brown Bat	P	P	P	X	
Northern Long-eared Bat	P	P	P	X	P
Silver-haired Bat	P	P	P	X	
Big Brown Bat	P	P	P	X	
Hoary Bat	P	P	P	X	X
Snowshoe Hare					P
Least Chipmunk					
Woodchuk					
Red Squirrel					P
Northern Flying Squirrel					P
Beaver	X	X	P	X	
Deer Mouse					
Southern Red-backed Vole					P
Heather Vole			P		P
Meadow Vole		P	P		P
Muskrat	X	X	P	X	P
Northern Bog Lemming		X	P		P
Meadow Jumping Mouse		X	P		P
Porcupine					
Coyote			P		P
Gray Wolf					P
Red Fox			P		P
Black Bear					P
Marten		X		X	
Fisher		X		X	
Ermine					P
Least Weasel					P
Mink		X	P	X	P
Wolverine					X
Striped Skunk					
River Otter	X	X	P	X	P
Canada Lynx					P
Mule Deer					
White-tailed Deer					
Moose		X	P		P
Species Richness	8	16	18	10	28
Richness Index	0.20	0.40	0.50	0.10	1.00

X indicates species observed on Lease 13 Local Study Area
P indicates species potentially on Lease 13 Local Study Area

Table 3. Potential and Observed Use of Vegetation Communities by Amphibian and Reptile Communities in the Shell Lease 13 Local Study Area (Golder 1997)

Common Name	Open Water	Fen	Riparian	Marsh	Treed Bog Black Spruce
Canadian Toad		X	P	X	P
Stripped Chorus Frog		X	P	X	P
Wood Frog		X	P	X	P
Red-sided Garter Snak		X	P	X	P
Species Richness	0	4	4	4	4
Richness Index	0.00	1.00	1.00	1.00	1.00

X indicates species observed on Lease 13 Local Study Area
P indicates species potentially on Lease 13 Local Study Area

APPENDIX F

SALINITY

APPENDIX F

SALINITY

TABLE OF CONTENTS

TABLES

APPENDIX F: SALINITY

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1. Introduction

In the oil sands region, salinity is not common in natural wetlands (bogs and fens) with the exception of a few salt meadows or saline lakes located in local discharge areas in northern Alberta (Fairbarns 1990, Timoney et al. 1997). For example, hydrological investigations of natural wetlands in Wood Buffalo Park by McNaugton (1991) indicated most electrical conductivities (EC) values are in the 0.5 to 3 mS/cm range with pH ranging from 7.2 to 8.7. The four major ion species vary widely in concentration with medians of sulfate (1700 ppm), calcium (500 ppm), bicarbonate (350 ppm) and magnesium (150 ppm). Lesser ions include chloride (55 ppm), sodium (47 ppm) and potassium (5.5 ppm). Oil sands mining will result in the creation of wetlands within the reclaimed landscape that receive saline waters. Salts present in certain overburden materials (Clearwater Formation and tailings sand) may be carried by groundwater discharge at the surface, thus affecting water quality seeping into constructed wetlands. This salinized water may discharge into shallow upland areas or wetlands and affect vegetation selection and growth. The addition of gypsum to make composite/consolidated tailings (CT) also results in elevated levels of soluble salts in groundwater percolating through this material. Consequently, salinity is a key issue that needs to be considered to attain success in dry land reclamation and wetland creation in the oil sands region.

2. Salinity Measurement

Salinity represents an estimate of the concentration of total dissolved inorganic solids or salts in water, as usually measured in total dissolved solids (TDS) or EC. For Alberta soils, the relationship between total dissolved solids and electrical conductivity is as follows (Stanley/SLN Consulting 1978):

$$\text{TDS (ppm)} = 850 \times \text{EC (mS/cm)}$$

Surface water quality classifications are usually based upon total salinity, generally measured as EC. Salinity of water within wetlands can be determined quite precisely by measuring TDS or EC. Unless samples are taken repeatedly throughout the year, such measurements can only approximately reflect the salinity of wetland waters since seasonal fluctuations occur as a result of dilution by runoff in the spring and progressive concentration due to evapotranspiration during the summer (Millar 1976). Table F1 relates salinity categories from a number of different disciplines. These disciplines include wetland classification, water quality, soils and vegetation.

3. Water Quality Standards for Salinity

Salinity of inland surface waters will have a significant impact on the potential end land uses that can be planned within the reclaimed landscape. The *Canadian Water Quality Guidelines* (CCME 1994) provide thresholds for salinity for several potential uses. For drinking water, the guidelines indicate that TDS ≤ 500 ppm is acceptable and is based primarily on aesthetic (palatability) considerations. For livestock watering, TDS of 5000-7000 ppm or EC of 8-11 mS/cm can be used with reasonable safety. Salinity does not appear to be a limiting factor for water-contact recreation, in terms of either concentration or constituent ions, provided that other factors such as pH and temperature fall within acceptable ranges.

4. Soil Salinity

The relationship between salinity and vegetation establishment for upland soils is well documented. For agriculture, severity of soil salinity (EC) on crop production has been classified into five categories (Alberta Agriculture) (Table F1). The *Land Capability for Forest Ecosystems in the Oilsands Region* (Leskiw, 1998) has also developed a relationship between soil salinity (EC) and the establishment of upland forest ecosystems (Table F1).

5. Vegetation Salt Tolerance

High salinity has a significant impact on vegetation establishment. High salinity forces plants to regulate salt intake and prevent dehydration through exertion of high internal osmotic pressure. Some species have adapted to tolerate higher levels of salinity, whereas other species are sensitive even to low levels of salinity. Moreover, some species are adaptive and vary osmotic pressure seasonally to adjust to seasonal changes in salt concentration, whereas other species have a narrow tolerance range due to dependence upon a consistent source of groundwater.

In developing a revegetation plan, it is useful to look at natural wetlands that have similar salinity levels to determine which plants are appropriate to revegetate created wetlands. Several inland surface water quality classifications for wetlands are based upon total salinity. For example, Millar (1976) modified a wetland classification proposed by Steward and Kantrud (1971) and proposed four groupings based on salinity: (1) Fresh (0.04-2 mS/cm); (2) Moderately Saline (2-15 mS/cm); (3) Saline (15-45 mS/cm); and (4) Hypersaline (more than 45 mS/cm) (Table F2).

Table F1: Relationships Among Salinity Categories from Different Scientific Disciplines

Wetland Salinity Class[1]	EC[1] (mS/cm)	TDS[1] (ppm)	Water Quality[2]	Soil Salinity (Agriculture[3]/Forestry[4])	Vegetation Salt Tolerance[3]
Fresh	0.04 – 2	34 – 1700	▪ suitable for drinking (500 ppm) ▪ suitable for livestock (5000 ppm) ▪ suitable for recreation (no limit)	▪ non-saline (< 2 mS/cm) ▪ 0–10 % reduction in forest productivity	low
Moderately Saline	2 – 15	1700 – 12750	▪ suitable for livestock ▪ suitable for recreation	▪ weakly saline (2-4 mS/cm) ▪ 10-30% reduction in forest productivity	low
				▪ moderately saline (4-8 mS/cm) ▪ 30-70% reduction in forest productivity	moderate
				▪ strongly saline (8-16 mS/cm) ▪ 70-100% reduction in forest productivity	high
Saline	15 – 45	12750 – 38250	▪ suitable for recreation	▪ very strongly saline (> 16 mS/cm) ▪ 100% reduction in forest productivity	very high
Hypersaline	> 45	> 38250	▪ suitable for recreation	▪ no potential for agriculture or forestry	none available

Sources:
1 Millar 1976
2 Canadian Council of Minister of the Environment 1994
3 Alberta Agriculture
4 Leskiw 1998

Both systems were developed for wetlands on the Canadian prairies. While soil salinity classes are considered transferable to the boreal forest, specific vegetation species growing in each ecological zone may differ.

Table F2: Wetland Salinity Categories with Stewart and Kantrud's (1971) Equivalents

Salinity Category		Salinity Range		
Code No.	**Name (EC mS/cm)**	**Dissolved Solids (ppm)[1]**	**Specific Conductivity (us/cm^3 at 25°C)**	**Stewart and Kantrud's Equivalent Salinity Class**
1	Fresh (<2)	< 28 - 1400	< 40 - 2000	A. Fresh B. Slightly Brackish
2	Moderately Saline (2-15)	1400 - 10500	2000 - 15000	C. Moderately Brackish D. Brackish
3	Saline (15-45)	10500 - 31500	15000 - 45000	E. Subsaline
4	Hypersaline (>45)	> 31500	> 45000	F. Saline

Source: Millar 1976
[1] Parts/million values are derived by multiplying conductance values by 0.7, the maximum ratio suggested by Thomas (1953)

Using these four categories, Millar has developed a list of plant species found in prairie wetlands, according to their wetland vegetation zone, salinity category and frequency of dominance relationship (Table F3). Zoltai et al. (1988) has also developed a list of plant species for wetlands of the prairies based on salinity class and wetland subform (Table F4). Both lists may be useful in selecting appropriate plant species lists for creating wetlands in the oil sands region.

Table F3: Principal Dominant Rooted Wetland Plant Species in the Prairies

	Saline categories with Code No. in which the species occurs[1]				Relative frequency with which species dominates its normal salinity range	
Wetland Vegetation Zones (Code No.) and species	**Fresh (1)**	**Moderately Saline (2)**	**Saline (3)**	**Hypersaline (4)**	**Common**	**Occasional**
Wet Meadow (1)						
Agrotis scabra	X					√
Calamagrostis canadensis	X				√	
Dechampsia caespitosa	X					√
Poa palustris	X	O			√	
Salix bebbiana	X	O			√	
Salix discolour	X	O			√	
Salix petiolaris	X	O			√	
Aster hesperius	X	O				√
Cirsum arvense[3]	X	O				√
Sonchus arvensis[3]	X	O			√	
Calamagrostis inexpansa	X	X			√	
Juncus balticus	X	X	O		√	
Hordeum jubatum	X	X	O		√	
Distichlis stricta	O	X	X		√	
Shallow Marsh (2)						
Phalaris arundinacea	X					√
Polygonum coccineum[3]	X	O			√	
Carex antherodes	X	O			√	
Alisma triviale[3]	X	O				√
Sparganium eurycarpum	X	O				√
Sium suave	X	O				√
Sagittaria cuneata	X	O				√
Scolochloa festucacea	X	X			√	
Eleocharis palustris	X	X			√	
Puccinellia nuttalliana		O	X		√	
Salicornia rubra		O	X		√	
Suaeda depressa		O	X			√
Emergent Deep Marsh (3)						
Scirpus validus	X				√	
Typha latifola	X	O			√	
Phragmites communis	X	X				√
Scirpus acutus	X	X			√	
Scirpus paludosus	O	X	X		√	

Table F3 continued…

	Saline categories with Code No. in which the species occurs[1]				Relative frequency with which species dominates its normal salinity range	
Wetland Vegetation Zones (Code No.) and species	**Fresh (1)**	**Moderately Saline (2)**	**Saline (3)**	**Hypersaline (4)**	**Common**	**Occasional**
Transitional Open Water (4)						
Potamogeton gramincus	X				√	
Utricularia vulgaris	X	O			√	
Potamogeton pusillus	X	O			√	
Rannuculus subrigidus	X	O				√
Shallow Open Water (5)						
Myriophyllum exalbescens	X	O			√	
Potamageton richardsonii	X	O				√
Ceratophyllum demersum	X	O				√
Potamogeton pectinatus	O	X	O		√	
Open Alkali (6)						
Ruppia maritima			X	X	√	
Disturbed[4] (7)						
Glyceria grandis (2)	X				√	
Chenopodium album (1)	X					√
Potentilla norvegica (1)	X					√
Rorippa islandica (1)	X					√
Thlaspi arvense (1)	X					√
Agropyron repens[3] (1)	X	O			√	
Beckmannia syzigachne (2)	X	O			√	
Alisma triviale[3] (1)	X	O				√
Alopecurus aequalis (2)	X	O				√
Polygonum coccineum[3] (2)	X	O			√	
Polygonum lapathifolium (2)	X	O				√
Cirsium arvense[3] (1)	X	O				√
Sonchus arvensis[3] (1)	X	O				√
Senecio congestus (2)	X	O			√	
Artemisia biennis (1)	X	X				√
Chenopodium rubrum (1)	X	X				√
Rumex maritimus (1)	X	X				√
Hordeum jubatum[3] (1)	X	X	O		√	
Aster brachyactis	O	X				√

Source: Millar 1976

[1] X and O indicate normal and subnormal development respectively.

[3] Commonly a pioneer species, but capable of maintaining dominance for long periods, hence it is listed for both stable and disturbed zones.

[4] Most disturbance species also occur as minor elements in stable vegetation zones. The number in parentheses after each species name is the code number for the stable vegetation zone with which it is commonly associated. The Disturbed Zone is usually dominated by a mixture of two or more species; hence, most species in this zone are listed here as occasional dominants.

Table F4: Characteristic Plant Species[1] Arranged According to Wetland Subform and Declining Salinity Levels[2] for Wetlands of the Prairies of Canada

	Wetland Subform			
Salinity Class (EC - mS/cm)	**Wet Meadow**	**Emergent Marsh**	**Permanent Open Water**	**Exposed Mudflat**
Hypersaline (>45)		*Salicornia europaea (ssp. rubra)* *Suaeda maritima*	*Navicula sp.* *Dunaliella sp.* *Rhizoclonium sp.* *Nitschia sp.* *Ruppia maritima*	
Saline (15-45)	*Distichlis stricta* *Triglochin maritima* *Spartina gracilis*	*Scirpus maritimus* *Puccinellia nuttalliana* *Scirpus americanus*	*Stephanodiscus sp.* *Chaetoceros sp.* *Pediastrum sp.* *Cladophora sp.* *Ruppia maritima*	
Moderately Saline (2-15)	*Spartina pectinata* *Glaux maritima* *Hordeum jubatum* *Juncus balticus*	*Eleocharis palustris* *Scolochloa festucacea* *Scirpus lacustris (ssp. glaucus)* *Phragmites australis*	*Fragilaria sp.* *Chaetoceros sp.* *Anabaena sp.* *Microcystis sp.* *Oscillatoria sp.* *Potamogeton pectinatus* *Zannichellia palustris* *Chara sp.* *Lemna trisula*	*Chenopodium rubrum* *Chenopodium glaucum (var. salinum)* *Rumex maritimus* *Hordeum jubatum* *Spergularia marina*
Fresh (<2)	*Poa palustris* *Calamagrostis canadensis* *Carex praegracilis* *Boltonia asteroides* *Sonchus arvensis* *Mentha arvensis*	*Typha latifolia* *Scirpus lacustris (ssp. validus)* *Carex antherodes* *Carex aquatilis* *Alisma plantago-aquatica* *Spargonium eurycarpum* *Sium suave* *Polygonum coccineum*	*Ceratophyllum demersum* *Myriophyllum spicatum* *Potamogeton perfoliatus (ssp. richardsonii)* *Potamogeton gramineus* *Potamogeton pusillus* *Utricularia vulgaris* *Drepanocladus sp.*	*Senecio congestus* *Eleocharis acicularis*

Source: Zoltai 1998

[1] Species assembled from Looman (1981, 1982), Hammer et al. (1983), Millar (1976) and Stewart and Kantrud (1972). Species are community dominants.

[2] Although listed in a single salinity class, some species are tolerant of a wide range of salinities.

An excellent list of dryland and wetland species adapted to salt affected areas in northern Alberta was compiled by a reconnaissance inventory by Fairbarns (1990). Fairbairns divided salt meadows in Northwestern Alberta into four habitat types based on moisture regime: (1) Marsh; (2) Marsh Meadow; (3) Wet Meadow; and (4) Dry Meadow. In addition, these habitat types were subdivided according to salinity (Table F5). In his study, Fairbarns visited three salt meadows in northwestern Alberta (Child Lake – CL, High Level – HL and Hay River – HR) and evaluated the extent of species present, as well as, the occurrence of halophytes, species adapted to elevated salt concentrations, at each site. Table F6 is a comprehensive list of plant species observed at these sites. This list may assist a planner in developing a suitable plant species list for revegetating wetlands or it may be used to compare revegetation success of reclaimed wetlands in the oil sands region to naturally occurring wetlands in northern Alberta.

TableF5: Community Types of Northern Salt Meadow Areas

Moisture Regime	Salinity	Vegetation Type (Indicator Species)
Marsh	Light	*Typha latifola – Scirpus validus* (cattail – great bulrush)
Marsh Meadow	Light	*Scolochloa festucacea – Galium trifidum* (spangletop – marsh bedstraw)
	Moderate	*Scirpus paludosus – Eleocharis palustris* (prairie bulrush – creeping spike rush) *Deschampsia cespitosa – Rumex occidentalis* (tuft hair grass – western dock)
Wet Meadow	Moderate	*Calamagrostis inexpansa – Carex spp.* (northern reed grass – sedge) *Hordeum jubatum - Deschampsia cespitosa – Eleocharis palustris* (foxtail barley – tufted hair grass – creeping spike rush)
Dry Meadow	Light	*Agropyron trachycaulum – Hierochloe odorata* (slender wheatgrass – sweet grass)
	Moderate	*Hordeum jubatum – Aster ericoides* (foxtail barley-tufted prairie aster)
	Strong	*Plantago eriopoda* (saline plantain) *Grindelia squarrosa – Glaux maritima* (Gumweed – Sea milkwort
	Extreme	*Puccinellia nuttalliana – Salicornia europaea*

Source: Fairbarns 1990

Table F6. Vascular Flora from Salt Meadows in Northwestern Alberta

Species	Location[1]	Occurrence// Abundance	Habitat Type
Achillea millefolium (Common Yarrow)	CL, HL, HR	Frequent/ scarce	Lightly to moderately saline wet and dry meadows
Achillea sibirica (Yarrow)	HL	Occasional/ scarce	Wet meadows
Agrohordeum macounii (Macoun's Wild Rye)	CL, HL		
Agropyron trachycaulum (Slender Wheatgrass)	CL, HL, HR	Frequent/ abundant	Lightly to moderately saline wet and dry meadows
Agrostis scabra (Tickle Grass)	CL, HL, HR	Frequent/ abundant	Wet and dry meadows
Allium schoenoprasum (Wild Chives)	HR	Occasional/ scarce	Lightly saline wet meadows
Androsace septentrionalis (Fairy Candelabra)	CL, HR	Infrequent/ scarce	Lightly saline dry meadows
Anemone multifida (Cut-leaved Anemone)	CL	Occasional/ scarce	Lightly saline dry meadows
Antennaria parvifolia (Pussy-toes)	CL, HL, HR	Frequent/ abundant	Lightly to moderately saline dry meadows
Arabis hirsuta (Rock Cress)	CL	Occasional/ scarce	Lightly saline dry meadows
Arnica chamissonis	HL	Occasional/ scarce	Lightly saline dry meadows
Artemesia biennis (Biennial Sagewort)	CL	Occasional/ scarce	Moderately saline dry meadows
Artemesia campestris (Wormwood)	CL	Occasional/ scarce	Lightly saline dry meadows
Artemesia tilesii (Wormwood)	CL, HR	Occasional/ scarce	Dry meadows
Aster borealis			Wet meadows
Aster brachyactis (Rayless Aster)	CL, HR	Frequent/ abundant	Moderately saline wet and dry meadows
Aster ciliolatus (Lindley's Aster)	CL, HL, HR	Infrequent/ scarce	Lightly saline dry meadows
Aster ericoides (Tufted White Prairie Aster)	CL, HL, HR	Frequent/ abundant	Moderately to strongly saline wet and dry meadows
Aster falcatus (Creeping White Prairie Aster)	HR	Infrequent/ scarce	Lightly saline dry meadows
Aster hesperius (Western Willow Aster)	CL, HL, HR	Frequent/ abundant	Moderately saline wet and dry meadows
Aster laevis (Smooth Aster)	CL, HL, HR	Occasional/ scarce	Lightly saline dry meadows
Aster pauciflorus		Common	Salt meadows
Aster bisulcatus			Salt meadows in Northwestern Alberta

Table F6 continued…

Species	Location	Occurrence/ Abundance	Habitat Type
Astragalus dasyglottis (Milk Vetch)	CL, HL, HR	Frequent/ Scarce	Lightly to moderately saline dry meadows
Atriplex nuttallii (Salt Sage)			Salt meadows in Northwestern Alberta
Atriplex prostrata (Salt Sage)	CL, HR	Occasional/ scarce	Extremely saline dry meadows
Astragalus striatus (Milk Vetch)	CL		Lightly to moderately saline dry meadows
Atriplex prostrata (Saltbush)	CL, HR	Occasional/ scarce	Extremely saline dry meadows
Beckmannia syzigachne (Slough Grass)	CL, HL, HR	Frequent/ scarce	Lightly to moderately saline marshes, marsh meadows and wet meadows
Bromus ciliatus (Fringed Brome)	HL	Occasional/ scarce	Moderately saline wet meadows
Calamagrostis canadensis (Bluejoint)	CL, HL, HR	Frequent/ abundant	Lightly to moderately saline marshes, marsh meadows and wet meadows
Calamagrostis inexpansa (Northern Reed Grass)	CL, HL, HR	Frequent/ abundant	Lightly to moderately saline marsh meadows and wet meadows
Calla palustris (Water Arum)	HL	Occasional/ scarce	Marshes
Callitriche verna (Water-starwort)	HR	Scarce	Marshes
Campanula rotundifolia (Bluebell)	CL	Occasional/ scarce	Lightly saline dry meadows
Carex aquatilis (Sedge)	CL, HL, HR	Rarely abundant	Lightly saline marshes and marsh meadows
Carex antherodes (Sedge)	CL, HL, HR	Frequent/ abundant	Lightly to moderately saline marsh meadows and wet meadows
Carex buxbaumii (Sedge)		Scarce	Salt meadows in Northwestern Alberta
Carex diandra (Sedge)	HL	Frequent	Lightly saline marsh meadows
Carex lasiocarpa (Sedge)	HL	Scarce	Salt meadows in Northwestern Alberta
Carex praegracilis (Sedge)	CL, HL	Frequent/ abundant	Moderately saline wet meadows
Carex practicola (Sedge)	CL	Occasional/ scarce	Moderately saline wet meadows
Carex rostrata (Sedge)	HL	Occasional/ scarce	Lightly to moderately saline marsh meadows and wet meadows
Carex sartwellii (Sedge)	HL, HR	Occasional/ scarce	Wet meadows
Certastium arvense (Mouse-ear Chickweed)	CL	Frequent/ scarce	Lightly to moderately saline dry meadows
Chenopodium album (Lamb's-quarters)	HL, HR	Occasional/ scarce	Moderately to strong saline dry meadows

Table F6 continued…

Species	Location	Occurrence/ Abundance	Habitat Type
Chenopodium rubrum (Red Goosefoot)	HL, HR	Infrequent/ scarce	Moderately to strong saline dry meadows
Chenopodium salinum (Oak-leaved Goosefoot)			Salt meadows in Northwestern Alberta
Cicuta maculata (Water Hemlock)	CL, HL, HR	Frequent/ abundant	Lightly saline marshes, marsh meadows and wet meadows
Cirsium drummondii (Drummond's Thistle)	CL	Infrequent/ scarce	Lightly saline dry meadows
Comandra umbellata (Bastard Toad-flax)	CL	Infrequent/ scarce	Lightly to moderately saline dry meadows
Crepis tectorum (Annual Hawksbeard)	CL, HL	Infrequent/ scarce	Lightly to moderately saline dry meadows
Danthonia califorinica (Oat Grass)	CL, HR	Infrequent/ scarce	Moderately saline dry meadows
Deschampsia cespitosa (Tuft Hair Grass)	CL, HL, HR	Frequent/ abundant	Moderately to strongly saline marsh meadows, wet and dry meadows
Distichlis stricta (Salt Grass)	CL, HL, HR	Frequent/ abundant	Moderately to strongly saline wet and dry meadows
Dodecatheon pulchellum (Shooting Star)		Abundant	Dry meadows
Elaeagnus commutata (Silver-berry)	CL	Infrequent/ abundant	Lightly saline dry meadows
Eleocharis acicularis (Spike Rush)	HL	Infrequent/ abundant	Lightly to moderately saline marshes
Eleocharis palustris (Spike Rush)	CL, HL, HR	Frequent/ abundant	Moderately saline marsh meadows and wet meadows
Epilobium angustifolium (Fireweed)	HL, HR	Scarce	Lightly saline dry meadows
Epilobium palustre (Willow-herb)	CL, HL, HR	Frequent/ scarce	Moderately saline marshes, marsh meadows and wet meadows
Erigeron acris (Fleabane)	CL, HL, HR	Infrequent/ scarce	Lightly to moderately saline dry meadows
Erigeron glabellus (Fleabane)	HL	Scarce	Lightly saline dry meadows
Erysimum cheiranthoides (Wormseed Mustard)	HL, HR	Occasional/ scarce	Lightly saline wet and dry meadows
Erysimum inconspicuum (Small-flowered Rocket)			Salt meadows in Northwestern Alberta
Festuca saximontana (Fescue)	CL	Scarce	Lightly saline dry meadows
Fragaria virginiana (Wild Strawberry)	CL, HL	Frequent/ scarce	Lightly saline dry meadows
Galium borealei (Northern Bedstraw)	CL, HL, HR	Frequent/ moderately abundant	Lightly saline dry meadows

Table F6 continued…

Species	Location	Occurrence/ Abundance	Habitat Type
Galium trifidum (Small Bedstraw)	CL, HL, HR	Frequent/ abundant	Lightly to moderately saline marshes, marsh meadows and wet meadows
Gentianella amarella (Felwort)	CL, HL	Occasional	Lightly saline dry meadows
Gentianella detonsa (Fringed Gentian)		Abundant	Wet meadows
Geum aleppicum (Yellow Avens)	CL, HL	Occasional	Moderately saline wet meadows
Geum macrophyllum (Yellow Avens)	HL, HR	Occasional	Moderately saline wet meadows
Geum triflorum (Old Man's Whiskers)	CL	Infrequent	Lightly saline dry meadows
Glaux maritima (Sea milkwort)	CL, HL, HR	Frequent/ abundant	Moderately to extremely saline wet and dry meadows
Glyceria grandis (Manna Grass)		Common	Marshes and marsh meadows
Glyceria pulchella (Manna Grass)	CL, HL, HR	Frequent/ occasionally abundant	Lightly saline marshes and marsh meadows
Grindelia squarrosa (Gumweed)	CL, HL, HR	Frequent/ abundant	Moderately to strongly saline dry meadows
Hedysarum alpinum		Common	Dry meadows
Helenium autumnale (Sneezeweed)	CL, HL, HR	Occasional/ scarce	Moderately saline dry meadows
Hieracium umbellatum (Narrow-leaved Hawkweed)	CL, HL, HR	Frequent/ occasionally abundant	Lightly to moderately saline wet and dry meadows
Hierochloe odorata (Sweet Grass)	CL, HL, HR	Frequent/ abundant	Moderately saline wet and dry meadows
Hippuris vulgaris (Mare's-tail)	HL, HR	Frequent/ abundant	Lightly saline marshes
Hordeum jubatum (Foxtail Barley)	CL, HL, HR	Frequent/ abundant	Moderately saline wet and dry meadows
Iva axillaris (Marsh Elder)			Salt meadows in Northwestern Alberta
Juncus balticus (Wire Rush)	CL, HL, HR	Frequent/ abundant	Lightly to strongly saline marsh meadows, wet meadows and dry meadows
Juniperus horizontalis (Creeping Juniper)		Common	Dry meadows at forest edges
Koeleria macrantha (June Grass)	CL	Infrequent/ scarce	Lightly saline dry meadows
Lactuca pulchella (Common Blue Lettuce)	CL, HL, HR	Frequent/ occasionally abundant	Lightly to moderately saline dry meadows

Table F6 continued…

Species	Location	Occurrence/ Abundance	Habitat Type
Lemna minor (Common Duckweed)	HL, HR	Frequent/ often abundant	Lightly saline marshes
Lemna trisulca (Ivy Duckweed)	CL, HL, HR	Frequent/ often abundant	Lightly saline marshes
Lepidium densiflorum (Common Peppergrass)	CL, HR	Infrequent/ scarce	Moderately to strongly saline dry meadows
Linum lewsii (Wild Blue Flax)		Occasional	Saline dry meadows
Lomatogonium rotatum (Marsh Felwort)		Common	Wet meadows
Mentha arvensis (Wild Mint)	CL, HL	Occasional/ scarce	Moderately saline wet meadows
Muhlenbergia richardsonis (Mat Muhly)	CL	Occasional/ scarce	Strongly saline dry meadows
Myriophyllum exalbescens (Water-milfoil)	HR	Occasional	Marshes
Orthocarpus luteus (Owl-clover)	CL	Occasional/ sometimes abundant	Moderately saline dry meadows
Oxytropis splendens (Showy Loco-weed)	CL	Infrequent/ scarce	Lightly to moderately saline dry meadows
Petasites sagittatus (Arrow-leafed Coltsfoot)	CL, HL, HR	Frequent/ occasionally abundant	Lightly to moderately saline wet and dry meadows
Phalaris arundinacea (Reed Canary Grass)			Marshes and marsh meadows
Phragmites australis (Reed)			Marshes and marsh meadows
Picea glauca (White Spruce)		Occasional	Lightly saline dry meadows
Plantago eriopoda (Plantain)	CL, HL, HR	Frequent/ abundant	Strongly saline dry meadows
Plantago maritima (Plantain)		Common	Saline dry meadows
Poa arida (Plains Bluegrass)	CL	Infrequent/ scarce	Strongly saline dry meadows
Poa canbyi (Piper)			Salt meadows in Northwestern Alberta
Poa pratensis (Kentucky Bluegrass)	CL, HL, HR	Frequent/ scarce	Lightly to moderately saline wet and dry meadows
Polygonum amphibium (Water smartweed)	CL, HR	Occasional/ scarce	Lightly saline marshes
Polygonum arenastrum (Common Knotweed)	CL	Occasional/ uncommon	Moderately saline dry meadows

Table F6 continued…

Species	Location	Occurrence/ Abundance	Habitat Type
Polygonum erectum (Striate Knotweed)			Salt meadows in Northwestern Alberta
Polygonum ramosissimum (Striate Knotweed)	CL, HL, HR	Frequent/ rarely abundant	Lightly to moderately saline marsh meadows and wet meadows
Potamogeton pectinatus (Sago Pondweed)	HR		
Pontentilla anserina (Silverweed)	CL, HL, HR	Frequent/ occasionally abundant	Lightly to moderately saline wet and dry meadows
Pontentilla arguta (White Cinquefoil)			Dry prairies
Pontentilla gracilis (Graceful Cinquefoil)	HR	Rare	Lightly saline dry meadows
Pontentilla norvegica (Rough Cinquefoil)	HL	Occasional/ scarce	Disturbed moderately saline dry meadows
Pontentilla pensylvancia (Cinquefoil)	CL, HL	Occasional/ scarce	Lightly saline dry meadows
Primula incana (Mealy Primrose)	CL, HL, HR	Infrequent/ scarce	Lightly saline dry meadows
Puccinellia nuttalliana (Alkali Grass)	CL, HL, HR	Frequent/ often abundant	Moderately to extremely saline wet and dry meadows
Ranunculus cymbalaria (Seaside Crowfoot)	CL, HL, HR	Frequent/ occasionally abundant	Lightly saline marshes and marsh meadows
Ranunculus sceleratus (Seaside Crowfoot)	CL, HL, HR	Infrequent	Lightly saline marshes and marsh meadows
Rhinanthus minor (Yellow Rattle)	HL	Rare	Moderately saline dry meadows
Ribes oxyacanthoides (Wild Gooseberry)	CL, HL, HR	Infrequent/ scarce	Lightly saline dry meadows
Rorippa palustris (Yellow Cress)	HL	Infrequent/ scarce	Moderately saline marsh meadows
Rosa acicularis (Prickly Rose)	CL, HL, HR	Frequent/ occasionally abundant	Lightly saline dry meadows
Rumex maritimus (Golden Dock)	CL, HL	Frequent/ occasionally abundant	Moderately saline marsh meadows and wet meadows
Rumex occidentalis (Western Dock)	CL, HL, HR	Frequent/ often abundant	Lightly to moderately saline marsh meadows and wet meadows
Sagittaria cuneata (Arrowhead)	HL	Occasional/ scarce	Lightly saline marshes and marsh meadows

Table F6 continued…

Species	Location	Occurrence/Abundance	Habitat Type
Salicornia europaea (Samphire)	CL, HL, HR	Frequent/ often abundant	Strongly and extremely saline dry meadows
Salix bebbiana (Willow)	CL, HL, HR	Frequent/ occasionally abundant	Lightly saline marsh meadows
Salix discolor (Willow)	CL, HL, HR	Infrequent/ scarce	Lightly saline marsh meadows
Salix petiolaris (Willow)	HL	Frequent/ occasionally abundant	Lightly saline marshes and marsh meadows
Scholochloa festucacea	CL, HL, HR	Frequent/ abundant	Lightly saline marshes and marsh meadows
Scirpus acutus (Great Bulrush)	HR	Occasional	Marshes
Scirpus paludosus (Prairie Bulrush)	CL, HL, HR	Frequent/ abundant	Moderately saline marshes and marsh meadows
Scirpus validus (Common Great Bulrush)	CL, HL, HR	Frequent/ abundant	Marshes
Shepherdia canadensis (Buffalo-berry)	CL, HR	Occasional/ scarce	Lightly saline dry meadows
Sisyrinchium montanum (Blue-eyed Grass)	CL, HR	Infrequent/ scarce	Lightly saline dry meadows
Sium suave (Water Parsnip)	CL, HL, HR	Frequent/ often abundant	Lightly to moderately saline marshes, marsh meadows and wet meadows
Smilacina stellata (Star-flowered Solomon's Seal)	CL, HL, HR	Occasional	Lightly saline dry meadows
Solidago canadensis (Canada Goldenrod)	CL, HL, HR	Infrequent/ occasionally abundant	Lightly saline dry meadows
Solidago nemoralis (Goldenrod)	HR	Occasional/ scarce	Lightly saline dry meadows
Sonchos uliginosu (Perennial Sow Thistle)	CL, HL, HR	Occasional/ scarce	Lightly to moderately saline dry meadows
Sparganium angustifolium (Bur-reed)	HL, HR	Occasional/ scarce	Lightly saline marshes
Spartina gracilis (Cord Grass)	CL, HR	Occasional/ scarce	Moderately to strongly saline dry meadows
Spergularia marina (Sand Spurry)	HR	Occasional/ scarce	Strongly to extremely saline dry meadows
Stachys palustris (Hedge Nettle)	CL, HL, HR	Frequent/ occasionally abundant	Lightly to moderately saline wet meadows and marsh meadows
Stellaria crassifolia (Chickweed)	HR	Occasional/ scarce	Lightly saline marsh meadows

Table F6 continued…

Species	Location	Occurrence/ Abundance	Habitat Type
Stellaria longifolia (Long-leaved Chickweed)	CL, HL, HR	Infrequent/ scarce	Lightly saline marsh meadows
Stellaria longipes (Long-stalked Chickweed)	CL, HL, HR	Occasional/ scarce	Lightly to moderately saline dry meadows
Suaeda calceoliformis	CL, HL, HR	Frequent/ abundant	Strongly and extremely saline dry meadows
Symphoricarpos albus (Snowberry)	CL, HL, HR	Occasional/ scarce	Lightly saline dry meadows
Symphoricarpos occidentalis (Buckbrush)	CL, HL	Occasional/ scarce	Lightly saline dry meadows
Taraxacum officinale (Common dandelion)	CL, HL, HR	Occasional/ scarce	Lightly to moderately saline wet and dry meadows
Thalictrum venulosum (Veiny Meadow Rue)	CL, HL, HR	Infrequent/ scarce	Lightly saline wet and dry meadows
Triglochin maritima (Arrow-grass)	CL, HL, HR	Frequent/ often abundant	Moderately saline marsh meadows and wet and dry meadows
Triglochin palustris (Slender Arrow-grass)	HR	Infrequent/ occasionally abundant	Moderately saline marsh meadows
Typha latifolia (Common Cattail)	CL, HL, HR	Frequent/ abundant	Lightly saline marshes and marsh meadows
Utricularia vulgaris (Common Bladderwort)	CL, HL, HR	Frequent/ often abundant	Lightly saline marshes
Vicia americana (Wild Vetch)	CL, HL, HR	Frequent/ scarce	Lightly to moderately saline wet and dry meadows
Viola adunca (Early Blue Violet)	CL, HL, HR	Infrequent/ scarce	Lightly saline dry meadows
Zizia aptera (Meadow Parsnip)	CL, HL	Infrequent/ scarce	Lightly to moderately saline dry meadows

Source: Fairbarns 1990

[1] CL = Child Lake HL = High Level HR = Hay River (see text)

Wall et al. (1999) studied the germination and survival of seeds of various plant species on various saline soils (i.e., ECs of 2, 10, 20, 30, 40 and 50). The species studied were not wetland species, however, they may be candidates for revegetation of saline upland areas adjacent to created wetlands. Table F7 classifies the plant species and varieties with respect to their best ability to germinate and emerge in saline seedbeds at various times of the year. Table F8 classifies the plants species and varieties percent survival of plant seedlings of different species grown in severely saline seedbeds listed by season.

Table F7: Classification of Plant Species and Varieties with Respect to Their Best Ability to Germinate and Emerge in Saline Seedbeds at Various Times of the Year

Dormant Fall Seeding	Spring Seeding	Fall or Spring Seeding
Chief Intermediate Wheatgrass	Adanac Slender Wheatgrass	Prairie Altai Wild Ryegrass
Kirk Crested Wheatgrass	James Dahurian Wild Ryegrass	Orbit Tall Wheatgrass
Durar Hard Fescue	Beaver and Rangelander Alfalfa	Tetracan Russian Wild Ryegrass
	Courtenay Tall Fescue	
	Garrison Creeping Foxtail	
	Signal Smooth Bromegrass	
	Rival Reed Canarygrass	

Source: Wall et al. 1999.

Table F8: Percent Survival of Plant Seedlings of Different Species Grown in Severely Saline Seedbeds Listed by Seeding Season

Fall Seeding	**0-25%**	**25-50%**	**50-75%**	**75-100%**
Spring Seeding				
0-25%	Rival RCG Durar HF Beaver A Rangelander A			
25-50%		Prairie AWR		
50-75%		Garrison CFT Signal SBG Adanac SWG James DWR		Kirk CWG Chief IWG
75-100%			Courtenay TF	Orbit TWG Tetracan RWR

Source: Wall et al. 1999.

6. Future Research

Future research needs to be conducted to determine the quantity of water infiltrating into the reclaimed substrates, as well as, to characterize the quality of water (e.g., salinity and hydrocarbons) after moving through the materials and entering wetlands. Since some surficial water and groundwater within the reclaimed landscape will acquire elevated levels of soluble salts, research needs to be conducted to identify salt tolerant plant species that can be used to revegetate both terrestrial and aquatic ecosystems in the boreal forest affected by salts. Since native plant species of the boreal forest are generally not salt tolerant, the research needs to examine the use of both native and agronomic plant species. However, research should try to identify local native species that could successfully establish in saline environments.

7. Waterfowl

The importance of salinity and its effects on adult waterfowl and ducklings vary considerably. For adult waterfowl the effects of salinity tend to be more indirect, that is, salinity influences plant and invertebrate communities which in turn determines the suitability of the habitat for adult waterfowl. Mobile adults have the ability to utilize a variety of habitats within their home range and thus have access to fresh water. Ducklings however, being less mobile are more susceptible to salinity levels in wetlands. Duckling tolerances to salt levels within wetlands are not as high as adults. Adults have functional salt glands while ducklings do not possess functional salt glands upon hatching. It is considered that salt glands are not functional until the ducklings are at least six days old. If during this period the ducklings do not have access to freshwater, salt concentrations can affect duckling survivability. In one study, ducklings less than 3 days old were exposed to water from wetlands which had chloride and sulfate concentrations ranging from 1,360 to 3,115 mg/liter and 8,750 to 27,500 mg/liter, respectively (Swanson et al 1984). These ducklings failed to survive and mortality routinely began after one day of exposure. As salt concentrations increased, the survival times of ducklings decreased.

Salt concentrations in wetlands can also affect growth rates. High salt concentrations not only limit weight gains but also the development of feathers.

A critical factor in the suitability of saline wetlands for ducklings is the availability of fresh water. In wetlands where freshwater seeps occur, chemically stratified water can occur. In sheltered areas, a thin layer of fresh water can occur over the more dense saline water. This freshwater layer can be sufficiently thick enough to be utilized by the ducklings and allow for improved survival rates.

While saline wetlands may not provide suitable habitat for ducklings, they can provide attractive habitat for breeding pairs.

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APPENDIX G

WATER QUALITY FROM DRAINED PEATLANDS

APPENDIX G: WATER QUALITY FROM DRAINED PEATLANDS

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Peatlands are an integral part of Canada's northern forests. They function as a transition zone between upland and aquatic ecosystems, storing and attenuating waters between these two zones, and affecting waters passing though them. In northern Alberta, both fens and bogs are known to alter downstream aquatic systems through base cation uptake and acidification (Halsey et al. 1997). Bogs particularly impact associated aquatic ecosystems through the generation of DOC associated acidity and color (Clausen 1981, Halsey et al. 1997). Rapid release of stored waters in peatlands associated with drainage and changes in the ability of a peatland to store and attenuate water also will impact downstream water quality (Clarke-Whistler et al. 1984). As the contribution of natural peatland ecosystems to aquatic systems is a function of their percent cover in the watershed (Halsey et al. 1997), the impact that harvested sites have on downstream water quality will be in part due to how much of the watershed is being disturbed. In addition, impacts will be relative to the chemistries of other water inputs to the watershed.

Studies examining the downstream impacts of peat harvesting on water quality have found decreases in pH, alkalinity, specific conductance, hardness, calcium, and magnesium, and increases in nitrate, turbidity, suspended solids, total organic carbon, and barium (Clausen and Brooks 1983, Washburn and Gillis Associates 1983). In addition Sallantaus (1984, 1986), and Sallantaus and Patila (1983) note an increase in nitrogen and phosphorus. Increases in DOC and ammonium were reported in downstream waters by Clausen (1980) and Moore (1987). However, Moore (1987) found that significant changes were short lived, and directly associated with ditching. Other reported changes in water quality have included increases in metal concentrations including iron (Clausen 1980, Selin 1996), and mercury (Westling 1991).

Traditional mitigative measures employed to reduce negative impacts on downstream water quality from peat harvesting have centered around the creation of siltation ponds for the trapping of suspended solids. The effect on removal of suspended solids is a function of pond maintenance, with occasional removal of solids from siltation ponds making them effective overall (Joensuu 1992, Wynne 1992). Failure to dredge can result in ponds acting as a suspended solids source and in some cases have been shown to decrease downstream water quality significantly (Wynne 1992, Joensuu 1992). Siltation ponds do not mitigate the amount of dissolved nutrients that can lead to eutrophication (Heikkinen 1990, Selin 1996).

In countries such as Finland where peatland usage is intensive, mitigation of nutrients and metals from peatland drainage waters has become an important issue (Huttunen et al. 1996). Following effective methods of wetland usage for mitigating nutrient loads from sewage waste (Surakka and Kamppi 1971, Tilton and Kadlec 1979, Kadlec and Hammer 1988), treatment of water emanating from peat harvesting sites has employed a similar technique. Termed overland flow, the conducting of water from peat harvested areas over a natural minerotrophic peatland (fen), potentially provides not only additional removal of suspended solids but also nutrients and metals through the processes of uptake by plants and microbes, absorption by peat, nitrification and subsequent denitrification (Huttunen et al. 1996).

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APPENDIX H

CONSTRUCTED WETLANDS FOR WATER TREATMENT

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CONSTRUCTED WETLANDS FOR WATER TREATMENT

TABLE OF CONTENTS

APPENDIX H: CONSTRUCTED WETLANDS FOR WATER TREATMENT

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The use of constructed wetlands (i.e., a specific biological treatment design incorporating principles of a fixed-film bioreactor) has been investigated by Suncor since such treatment wetlands may offer a cost effective alternative to conventional systems. The focus of the work was on "self-sustaining" treatment systems (i.e., with no ongoing manipulations).

1. Wetlands Design Criteria

A 1995 pilot-scale study at the Suncor Wetlands Research Facility focussed on an investigation of a managed wetlands operation for the biological treatment of various process-affected wastewaters. The rationale for this study was the need to enhance treatment performance; that is, to reduce the large area of land required for treatment. Also, with mine expansion a managed wetlands system could be maintained for many years in parallel with mine operations. The term "managed" conceptually includes any aspect of a wetlands design and/or operation requiring continuous inputs from managers; for example, the addition of nutrients and/or the construction of biological prefilters to remove ammonia. The use of alternating open ponds with marsh-like wetlands is also considered an aspect of a managed wetlands since the pond-wetland scenario would likely require the construction and maintenance of berms and, perhaps, occasional operational activities such as dredging to maintain areas of open water.

The use of wetlands to treat industrial wastewater is a relatively new biotechnology compared with conventional treatment systems; therefore, correspondingly new approaches will be required by regulatory agencies. For example, criteria are neded for effluent quality as well as for environmental acceptability (i.e., the habitat within the wetlands treatment area). In addition to their function as treatment systems, these wetlands would also create additional "natural" aquatic systems which would be part of the local environment. This situation contrasts with conventional engineered treatment systems which would be confined and hence isolated from the environment. As a consequence, any proposal to develop such treatment wetlands has environmental implications, both with respect to ecological benefits (e.g., increased habitat for waterfowl) or potential adverse impacts (e.g., the bioaccumulation of contaminants). Alberta Environment has developed a policy (AEP 1995a) and procedures manual (AEP 1995b) for industrial effluent limits which can be used to deal with water discharges from water treatment wetlands receiving process-affected waters.

In this study, the assessment factors for treatment performance were: changes in total concentrations of soluble and insoluble hydrocarbons (e.g., total extractable hydrocarbons, TEH) in the water column, as well as other contaminants such as naphthenic acid (NA) and ammonia; in situ mineralization rates between treatment vs. control wetlands; and, reductions in toxicity using a suite of laboratory and in situ test organisms. Conventional parameters of waste treatment efficiency (e.g., BOD5, COD) were not emphasized since contributions of organic matter/detritus from wetland plants could not be reliably documented and would likely confound interpretation of these data. Estimates of ecological acceptability were based on: field measurements of phytoplankton and zooplankton communities and a limited "scoping" investigation of contaminant bioaccumulation into waterfowl.

The two principal types of wastewater investigated in this study were:

- Dyke Drainage (DD) water - leachate from the tailings ponds dykes
- Consolidated Tails (CT) release water - water extracted from a CT flocculation process of the tailings using calcium sulphate

The overall study objectives were: 1) to determine water quality characteristics of effluent from each treatment system wetlands (i.e., treatment effectiveness); and 2) to assess the ecological characteristics of the treatment wetlands including selected chemical, toxicological, physical and biological characteristics (i.e., environmental acceptability).

In 1994, it was hypothesized that the mineralization of organic contaminants in Suncor's treatment wetlands for dyke drainage water (Hydraulic Retention Time or HRT = 18 d) was inhibited by a lack of oxygen. As a result, a pond (HRT = 41 d) was placed upstream of a wetlands trench (HRT = 8 d) in 1995. It was anticipated that the performance of the wetlands component would improve since: 1) the pond would increase oxygen levels in water flowing into the wetlands (i.e., through increased diffusion into the water column by the action of wind and waves); and, 2) microbial processes within the pond would decrease the oxygen demand of inflowing water (i.e., through nitrification of ammonia-ammonium and/or oxidation of organic compounds). The results indicate that the addition of a pond component to the wetlands treatment system dramatically improved treatment performance since:

- Dissolved oxygen levels for DD water entering the wetlands component from the pond were about twice as high as in 1994 when water flowed directly to the wetlands from a closed tank reservoir (i.e., 5.8 vs 3.0 mg/L).

- The average concentration of ammonia-ammonium in the wetlands outflow was less in 1995 from the pond-wetlands system compared with a wetlands alone in 1994, although removal rates (i.e., 150 mg/m2/day in the pond and 218 mg/m2/day in the wetlands in 1995 compared with 126 to 222 mg/m2/day in 1994) were comparable between the two years. The mean level of ammonia-ammonium nitrogen in the outflow of the replicate Dyke Drainage wetlands in 1994 was 3.7 mg/L compared with 0.9 mg/L for the pond-wetlands system this year. Therefore, better removal was achieved through a longer overall HRT (49 d compared with 18 d).

- The oxygen demand of inflowing DD water to the wetlands component of the treatment system was reduced by virtue of a 50% decrease in inputs of ammonia-ammonium, presumably allowing more oxygen in the water column of the wetlands to be diverted from nitrification (ammonia-ammonium oxidation) to the biodegradation of organic contaminants. In fact, on the basis of surface area, TEH (i.e., hydrocarbons) removal rates were 168 mg/m2/day for the pond and increased to 395 mg/m2/day for the wetlands component. This range compares with only approximately 104 mg/m2/day in 1994, indicating about a four fold increase in hydrocarbon removal per square metre of the wetlands (i.e., not the pond) in 1995. Since HRT increased from 18 to 49 d in parallel with increasing removal rates, a total of 132 gTEH/day were removed in the 1995 pond-wetlands system compared with only 18 g/day in 1994 - or about 7 times the removal rates in 3.1 times the amount of space (i.e., the 1995 pond-wetlands had a greater surface area).

- Finally, although only a modest decrease in trout acute toxicity was achieved in the pond component of the 1995 treatment system, the final outflow of DD water from the wetlands component was consistently non-toxic unlike 1994 water quality. For example, in 1994 the mean fish survival time (LT50) in the outflow was 16 to 39 h compared with > 96 h in 1995. However, evidence from chronic toxicity tests did not indicate better treatment; in fact, there was a decrease in the survival and reproduction of *Ceriodaphnia dubia* (an aquatic invertebrate) in 1995 compared with 1994. There was also a persistent chronic toxic effect as measured by the Microtox bacterial bioassay - the mean IC20 value was 15% in the inflow and increased to a mean of 31% at the wetlands outflow (i.e., the increase in IC20 values indicates some decrease in toxicity but a toxic effect was still evident since values were still less than non-toxic levels or an IC20 of 100%).

It was concluded that a pond-wetlands system (with phosphate) for the treatment of Dyke Drainage water was superior to a wetlands system alone. However, it is not certain that enhanced treatment was due to the pond component and/or phosphate addition. With an overall HRT of 49 d, effluent would meet regulatory effluent guidelines for trout toxicity (i.e., no acute toxicity), would have low, nontoxic levels of ammonia-ammonium, and would have an increased rate of hydrocarbon removal.

Notwithstanding the potential for sedimentation, turbidity levels for Dyke Drainage water did not decrease in the pond. This was attributed to low initial levels (mean = 13 NTU) and to the likely small sizes of the suspended particles (i.e., clay) which would tend to resist sedimentation.

2. Consolidated Tails Release (CT) Water

The treatment of CT water was tested in several ways: 1) in pits with no treatment; 2) in wetlands treatment trenches (with and without phosphate as a nutrient amendment) as had been done for Dyke Drainage water in previous years; and, 3) in a pond-wetlands system with phosphate additions to the pond. The HRT was 36 d in the pond and 10 d in each wetlands (compared with an HRT of 18 d in the 1994 Dyke Drainage wetlands).

There is some question regarding the quality of CT water used in the 1995 experiments; that is, whether it was comparable with CT water now produced operationally. However, the water used in 1995 appeared to contain more contaminants, and was more toxic, than CT water used in 1994 bench-scale experiments which was thought to be more representative. Therefore, any conclusions from these results might be considered as a worst-case scenario based on this assumption. Furthermore, the experimental design did not permit replication and hence these results should be considered preliminary.

CT water effluent quality from treatment wetlands exceeded ambient water quality and/or water quality guidelines for the following parameters: conductivity, TEH, COD, TOC, all the major ions (although magnesium was not consistent), iron, molybdenum, strontium and zinc. However, in some cases outflow water quality exceeded guidelines but did not exceed levels in nearby water bodies (e.g., Athabasca River, Ruth Lake, Crane Lake). Importantly, there are no regulatory guidelines for many of the above parameters and especially not for significant parameters such as TEH or naphthenic acids, probably primary toxicants in this water.

The pond to wetlands system was expected to produce better water quality than wetlands alone because it had an upstream phosphate amended pond pre-treatment system. However in general, treatment using a pond-wetlands system produced a quality of water comparable with a wetlands system alone. Therefore, a pond component may not be needed to treat CT release water.

Outflow water quality of the pond-wetlands system was improved in some respects compared with the pond alone or with wetlands alone. At the pond-wetlands outflow, levels of TEH and NA (likely the primary toxicants since ammonia was essentially absent in CT inflow water) were the lowest among the other wetlands outflows. As with the wetlands alone, generic classes of organic compounds (e.g., TOC, COD), were not removed. However, concentrations of zinc (0.017 mg/L) at the pond-wetlands outflow were less than Alberta water quality standards, which was not the case for both of the wetlands-only treatments where zinc actually increased from inflow to outflow. In terms of toxicity, both the pond-wetlands and wetlands-only outflow were not acutely toxic to rainbow trout; however the pond-wetlands had reduced survival (i.e., increased toxicity) for the aquatic invertebrate, *Ceriodaphnia dubia* compared with the wetlands-only trench treated with phosphate.

3. Impacts of Treatment Wetlands on Waterfowl

In a preliminary scoping experiment, mallard ducklings (*Anas platyrhynchos*) were exposed to the various CT and DD treatment wetlands using floating cages over a period of four weeks. The principal route of exposure was by ingestion of water.

There were no differences among treatment groups or between treatments and control groups in growth rate and there were no sign of gross organ pathology upon necropsy. All ducklings had moderate to heavy body fat.

There were also no liver metal residue differences between treatment groups, or between treatments and control. Nickel was the only metal found in feathers in elevated concentrations, and this was not correlated with exposure to wetlands water. Therefore, after exposure to both DD and CT waters in treatment wetlands, there was no uptake of metals sufficient to present a health risk to young mallards. Also, no uptake of PAHs (polycyclic aromatic hydrocarbons) was observed through analysis of bile PAH metabolites.

These data suggest that there is no health risk to migrating waterfowl. However, the study findings were preliminary because the principal exposure route was via water (i.e., ingestion of wetlands flora and fauna was limited). Further study is recommended because of the nature of the experimental design (i.e., limited exposure routes) and the importance of this component of the aquatic ecosystem.

4. Nutrients and Biological Treatment

Both laboratory and field work has shown that phosphate is a limiting nutrient with respect to the biodegradation of toxic contaminants in Suncor's process-affected waters such as Dyke Drainage and recycle waters from tailings ponds. Since the focus of much of Suncor's wetlands work has been as a "reclamation" technology (i.e., using self-sustaining, unmanaged wetlands that would treat water over long periods of time), nutrient supplementation experiments in the field have been limited. Phosphate supplementation is an extremely important factor which has the potential to dramatically enhance the rate of microbial detoxification and treatment of Dyke Drainage and/or tailings pond recycle water. The use of nutrient supplementation (including nitrogen) is an important factor in any investigation of constructed wetlands or other biological treatment processes and should be incorporated in any further research.

5. Design Criteria Summary for Dyke Drainage (DD) Water and CT Water in Wetlands

Design criteria for the amount of land and/or HRT required to treat Dyke Drainage and CT water in constructed wetlands or pond-wetlands system have been developed. Using four independent parameters (microbial mineralization rates, TEH and ammonia removal, and detoxification using trout as an acute toxicity bioassay organism), design criteria values were determined. Design criteria values ranged as follows: 1) for Dyke Drainage water treated in a wetlands alone, from 780 to 7100 m3/ha/month; for Dyke Drainage water treated in a pond-wetlands, from 2,100 to 6,100 m3/ha/month; and for CT water in a wetlands alone, from 4,300 to 9,000 m3/ha/month. These design criteria have a degree of uncertainty and the benefits of enhancement features (e.g., ponds) have only been explored in single experiments in 1995 and need to be confirmed.

Using a worst-case scenario as a basis for design (i.e., based on the complete removal of TEH compounds), it was considered appropriate to use the lowest criteria determined to date as follows:

Treatment Wastewater Loading Rate (m^3/ha/month based on flow rate of 10,000 L/min)

- Dyke Drainage pond-wetlands: 2,100 m^3/ha/month
- CT wetlands alone: 4,300 m^3/ha/month

The above criteria are based on the complete removal of TEH compounds, which may become a regulatory requirement since background levels in nearby water bodies and wetlands are low (e.g., 1 to 3 mg/L; Sander, 1996).

5.1 Dyke Drainage Water

Based on the available data and given the qualifications outlined in this report, the minimal treatment wetlands design for Dyke Drainage water in a pond-wetlands system would include.

- Inflow of 2,057 m^3 wastewater/ha/month (if current water quality occurs in the future).
- Mean wetland water depth of 0.3 m (with maximum < 0.5 m) in wetlands cells.
- Inflow and outflow control structures.
- HRT < 49 days.
- Length:width ratio of 2:1 at a minimum.
- Multiple cells.

- Planted with local types of vegetation (*Typha* and *Scirpus* species).
- No or minimal discharge during winter.
- Pond:Wetlands area ratio of about 2:1.
- Pond depth of 1.5 - 3 m in cells positioned in front of the first treatment wetlands cell (and between the wetlands cells).
- Nutrient additions to the first pond cell.

and could be further enhanced by:

- Subsurface gravel beds or biological filters prior to the first wetlands treatment cell (this additional treatment may aid in the removal of chronic toxicity in the downstream wetlands).

5.2 CT Release Water

Based on the available data and given the qualifications outlined in this report, the minimal treatment wetlands design for CT release water in a wetlands system would include:

Inflow of 4,264 m^3 wastewater/ha/month (if current water quality occurs in the future).

- Mean wetland water depth of 0.3 m (with maximum < 0.5 m) in wetlands cells.
- Inflow and outflow control structures.
- HRT < 10 days.
- Length:width ratio of 2:1 at a minimum.
- Multiple cells.
- Planted with local types of vegetation (*Typha* and *Scirpus* species).
- No or minimal discharge during winter.

and could be further enhanced by:

- Subsurface gravel beds or biological filters prior to the first wetlands treatment cell (this additional treatment may aid in the removal of chronic toxicity in the downstream wetlands).

These design criteria were based on data means. Prior to designing the treatment wetlands, the range of treatment observed should be considered, as would 100 and 1000 year storms be considered in the design for other engineered projects. As the studies used to derive these design criteria have occurred on a small scale (both spatially and temporally), it should be expected that once a full scale treatment wetlands is built it would require monitoring to demonstrate that treatment is complete at the desired water flows and release times. During this confirmation phase, discharge water could either be recycled through the wetlands or returned to a tailings pond.

APPENDIX I

TRADITIONAL PLANTS

APPENDIX I: TRADITIONAL PLANTS

John Gulley
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Table I1. Plants Gathered for Food, Medicine, Cultural and Spiritual Purposes in the Oil Sands Region

Traditional Name	Common Name	Scientific Name	Location [a]					
			Non-wetlands ecosites	Shallow open water areas	Marshes	Swamps	Fens	Bogs
	balsam fir	*Abies balsamifera*	X					
	beaked hazelnut	*Corylus cornuta*	X			INF		
Muskeg wire-grass	bearberry kinnikinik	*Arctostaphylos uva ursi*	X					
	birch - red (bog birch)	*Betula pumila*						X
	birch - white *(paper)	*Betula papyrifera*	X					
	black currant *	*Ribes hudsonianum*	X			X		
	black gooseberry	*Ribes oxacanthoides*	X			X	X	
Black poplar	balsam poplar	*Populus balsamifera*	X			X		
	black spruce	*Picea mariana*				X	X	X
	blueberry	*Vaccinium myrtilloides*	X					
	bog cranberry	*Vaccinium vitis-idaea*	X				X	
	bracted honeysuckle	*Lonicera involucrata*	X			INF		
	buffalo berry	*Shepherdia canadensis*	X			INF		
	bulrush	*Scirpus spp.*			X			
Pin berry	bunchberry	*Cornus canadensis*	X			X		
	cattail	*Typha latifolia*			X			
	chamomile	*Matricaria matricariodes*	X (DL)					
	chokecherry	*Prunus virginiana*	X					
Frog berry	cloudberry	*Rubus chamaemorus*					X	
Cow root	Cow parsnip	*Heracleum lanatum*	x			x		
Otterberry	crowberry	*Empetrum niguim*					x	x
	dewberry	*Rubus pubescebs*	X			X	INF	
Red willow	dogwood (red osier)	*Cornus stolonifera*	X			X		
	dwarf birch	*Betula pumila var. glandulifera*				X	X	X
	dwarf raspberry	*Rubus acaulis*	INF (transitional ecosites)			X	X	X
	fly honeysuckle	*Lonicera caerulea*	X			X	X	X
	frying pan plant							
	fungi							
	fungi - dry dead wood	*Echinodontium tinctorium*						

Traditional Name	Common Name	Scientific Name	Location [a]					
			Non-wetlands ecosites	Shallow open water areas	Marshes	Swamps	Fens	Bogs
	(red touchwood fungus)							
	fungi (puffball) ground fungus	*Lycoperdon spp.*						
	bracted fungus	*Fomes officinalis*						
	bracted fungus	*Fomes pinicola*						
	goldenrod	*Solidago canadensis*	X			INF		
	green alder *	*Alnus crispa*	X			INF		
	harebell	*Campanula rotundifolia*	X					
	high bush cranberry	*Viburnum opolus*	X			INF		
	honeysuckle fly	*Lonicera dioica var.glaucescens*				INF		
	huckleberry	*Vaccinium spp.*	INF					
	horsetail	*Equisetum spp.*	X (transitional ecosites)			X	X	X
	jack pine	*Pinus banksiana*	X					
	juniper	*Juniperus communis*	INF					
Muskeg tea	Labrador tea	*Ledum groenlandicum*	X			X	X	X
Caribou moss	lichen							
	lodgepole pine	*Pinus contorta var. latifolia*	INF			INF		
	low bush cranberry	*Viburnum edule*	X			X		
	marsh cinquefoil	*Potentilla palustris*						
Frying pan plant	marsh marigold	*Caltha palustris*						
	meadow rue	*Thalictrum venulosum*						
	mint	*Mentha arvensis*			X	INF		
Muskeg plant	Club moss	*Selaginella spp.*	Habitat varies depending upon species					
	nettle	*Urtica dioica ssp gracilis*	X (transitional ecosites)			INF		
	northern bedstraw	*Galium boreale*	X			X	X	X
	pin cherry	*Prunus pensylvanica*	X					
	pink wintergreen	*Pyrola asarifolia*	X					
green frog plant (frog pail)	Pitcher plant	*Sarracenia purpurea*					X	
	plantain *	*Plantago major*	X (DL)					
	prickly rose	*Rosa acicularis*	X			INF		
	raspberry	*Rubus idaeus*	X			INF	INF	
	red currant	*Ribes triste*	X (transitional ecosites)			X		
	red touchwood fungus							
	river alder	*Alnus tenufolia*	X			X		
	rock stripe	*Umbilicaria spp.*	X					
	saskatoon *	*Amelanchier alnifolia*	X			INF	INF	
	Seaside arrowgrass	*Triglochin palustris*		x	x		X	
	senega snakeroot	*Polygala senega*	X					

Traditional Name	Common Name	Scientific Name	Location [a]					
			Non-wetlands ecosites	Shallow open water areas	Marshes	Swamps	Fens	Bogs
	showy aster	*Aster conspicuus*	X			X		
buckbrush	snowberry	*Symphoricarpos albus*	X			INF		
	sphagnum moss	*Sphagnum spp.*					X	X
	stiff clubmoss	*Lycopodium annoitinum*	X (transitional ecosites)			X	X	X
	strawberry	*Fragaria virginiana*	X			INF	INF	
rat root	sweet flag	*Acorus calamus*			X			
Itch plant	Sweet gale	*Myrica gale*			x	x	X	
	sweet grass	*Hierochloe odorata*	X			X		
	Sweet potatoes		X					
	sweet-scented bedstraw	*Glaium trifolia*	X			X	INF	
	tamarack (larch)	*Larix laricina*				X	X	X
	tansy	*Tannesetum vulgare*	X (DL)					
	trailing raspberry	*Rubus pubescens*	X			X		
	trembling aspen *	*Populus tremuloides*	X			INF		
	canadian tuckahoe fungus	*Polyporus tuberaster*	X					
	twinning honeysuckle	*Lonicera dioica var.glaucescens*	X			X	X	X
	twisted stalk	*Streptotus amplexifolius*	X (transitional ecosites)		X	X		
	western dock	*Rumex occidentalis*				X	X	
	white spruce	*Picea glauca*	X			INF		
	white wintergreen	*Pyrola elliptica*	X			INF		
Rabbit root	wild sarsaparilla	*Aralia nudicaulis*	X					
	willow	*Salix spp.*	X			X		
	willow fungus							
	yarrow *	*Achillea millefolium*	X			X	X	X

[a] X = typically found in the location.
NF = infrequent, but may be present.
DL = disturbed land (i.e., these tend to be introduced species like chamomile).

APPENDIX J

RECLAMATION RESEARCH PRIORITIES

APPENDIX J
RECLAMATION RESEARCH PRIORITIES

TABLE OF CONTENTS

TABLES

APPENDIX J: WETLAND RECLAMATION RESEARCH PRIORITIES

Prepared by Oil Sands Wetlands Working Group

Table J1 provides the basis for determining the relative priority for wetlands research in the oil sands region. The table provides a significant amount of information, within three general categories.

1. Degree of Knowledge/Degree of Concern and Research Priority

The major issues associated with oil sands wetlands were identified under a number of broad issue areas for the three general types of oil sands landscapes (overburden, tailings sand, and CT deposits). To evaluate the priority for research on a specific issue for a specific landform, two factors were considered:

1. The degree of knowledge (i.e., the availability of information on this issue): a ranking of 1, 5 or 10 was given, where 1 equals a relatively high level of available information and 10 equals a low amount of information (or the need for more information); and
2. The degree of concern (i.e., what is the consequence or importance of this issue to understanding potential effects on the environment): a ranking of 1, 5 or 10 was given, where 1 equals a low degree of concern and 10 equals a high level of concern.

Once the level of knowledge and degree of concern were assigned for each issue area under each landform, the two rankings were multiplied and a score assigned (i.e., a requirement for research was determined). The degree of knowledge, degree of concern and scores are listed in the table in rows with the code “C”. Scores of 100 indicate the highest priority for research, with 50 indicating the second highest priority. All scores of 50 and 100 are highlighted on the table. A lower score does not mean that research is not required, but rather that such research is not of immediate concern.

2. Recommendation Cross-Reference

The Wetlands Working Group identified a number of recommendations for continued research or efforts in assessing the application of wetlands on oil sands reclamation landscapes. These recommendations are presented on Table 7.1 of the guideline. The recommendations applicable to the various issues and landscapes are listed in the Table J1 in the rows with the code “R”.

3. Research Project Cross-Reference

Appendix K lists wetlands-related projects completed, or currently in progress under the Canadian Oil Sands Network for Research and Development (CONRAD). The information from these projects is used, in part, to provide a concern ranking for each issue / landscape area. The research projects applicable to the various issues and landscapes are listed in Table J1 in rows with the code “P”.

Table J1. Summary of Wetland Knowledge, Degree of Concern, Consequence and Score (i.e., Requirement for Research), As Well As Cross-Reference to Recommendations Of Wetlands Working Group and Cross Reference to Completed Research

Issue	Code (a)	Overburden	Score	Tailings Sand	Score	Consolidated / Composite Tailings (CT)	Score
Chemistry							
Solids	C	1 x 5	5	1 x 1	1	1 x 10	10
	R	None		None		35, 38, 39	
	P	None		23, 24, 25, 61		24, 25	
Water - Salinity	C	10 x 5	**50**	1 x 5	5	10 x 10	**100**
	R	1, 2		1, 2		1, 2, 35, 36, 37, 39	
	P	10		10		9, 17, 20	
Naphthenic Acids /Organics	C	1 x 1	1	1 x 10	10	5 x 10	**50**
	R	1, 2		1, 2		1, 2, 35, 36, 37, 39, 49, 50, 51	
	P	10		1, 2, 7, 10, 12, 13, 48, 49, 50, 67, 57, 58, 60, 61, 62		1, 2, 8, 9, 17	
Metals	C	1 x 1	1	1 x 1	1	1 x 10	10
	R	1, 2, 31; 32; 34		1, 2, 31; 32; 34; 60		1, 2, 31; 32; 34; 35; 36; 37; 39	
	P	10,		3, 7, 10, 13, 56, 57, 58, 61		8, 9, 17	
Water Release Rates	C	1 x 1	1	5 x 10	**50**	10 x 10	**100**
	R	1, 3, 4, 5		1, 3,4, 5		1, 3,4, 5, 35; 37; 38	
	P	None		23		None	
Treatment Capability	C	10 x 1	10	1 x 10	10	10 x 10	**100**
	R	1, 2, 3, 4, 5, 6, 8		1, 2, 3, 4, 5, 6, 8,		1, 2, 3, 4, 5, 6, 8,	
	P	None		2, 3, 6, 7, 13, 18		2, 6, 8, 9, 17, 18	
Biology							
Diversity	C	5 x 5	25	5 x 5	25	10 x 10	**100**
	R	1, 7, 8, 9, 11, 12, 65, 66, 70		1, 7, 8, 9, 11, 12, 65, 66, 70		1, 7, 8, 9, 10, 11, 12, 40, 41, 42, 43, 44, 45, 46, 47, 56, 58, 65, 66, 70	
	P	10, 14, 30, 31		10, 13, 14, 18, 29, 30, 31, 41, 42, 43, 44, 45, 59, 64		14, 17, 18, 20, 21, 32, 33, 34, 35, 36, 37, 38, 39, 40, 46, 47	
Bioaccumulation	C	5 x 10	**50**	5 x 10	**50**	10 x 10	**100**
	R	1, 8, 31; 32; 33; 34; 66		1, 8, 31; 32; 33; 34; 66		1, 8, 31; 32; 33; 34; 45; 46; 47; 50; 66	
	P	24		3, 4, 11, 13, 18, 24, 25, 26, 27, 58, 60, 64		4, 17, 18, 21, 24, 25, 26, 27, 32, 33, 34, 35, 40, 55	

Chronic Toxicity	C	10 x 5	**50**	10 x 10	**100**	10 x 10	**100**
	R	1, 3, 4, 8		1, 3, 4, 8		1, 3, 4, 8, 41; 43; 45; 46; 47; 48; 50; 56	
	P	10, 24		3, 5, 6, 7, 10, 11, 13, 18, 24, 25, 26, 27, 41, 42, 43, 44, 45, 49, 51, 52, 53, 54, 56, 57, 58, 59, 61, 64		3, 6, 8, 9, 17, 18, 20, 21, 24, 25, 26, 27, 32, 33, 34, 35, 36, 37, 38, 39, 40, 46, 47, 55	
Riparian Area	C	10 x 1	10	10 x 5	**50**	10 x 10	**100**
	R	9		9		9, 40; 44; 45; 58; 60	
	P	None		None		20	
Connectors (Streams between areas)	C	10 x 1	10	5 x 10	**50**	10 x 10	**100**
	R	9, 13		9, 13		9, 13, 40; 41; 42; 43; 44; 45; 58; 60	
	P	10		10		20	
Revegetation Requirements	C	1 x 1	1	1 x 1	1	10x 5	**50**
	R	1, 70		1, 70		1, 40; 41; 42; 43; 44; 58; 70	
	P	None		3, 13, 18, 24, 25, 26, 27, 28, 29		17, 18, 20, 24, 25, 26, 27, 36, 37	
Air Quality							
Air – releases from wetlands	C	10 x 1	10	10 x 1	10	10 x 5	**50**
	R	53; 54; 55		53; 54; 55		53; 54; 55	
	P	None		None		None	
Air – impact from acidifying emissions	C	10 x 1	10	10 x 1	10	10 x 1	10
	R	52		52		52	
	P	None		None		22	
Physical							
Hydrology	C	1 x 10	10	5 x 10	**50**	10 x 10	**100**
	R	1, 3, 5, 9, 61, 62, 63, 64, 67		1, 3, 5, 9, 61, 62, 63, 64, 67		1, 3, 5, 9, 61, 62, 63, 64, 67	
	P	15		6, 15		6, 15	
Traditional Land Use							
Traditional Uses and End Use of Reclamation Wetlands	C	10 x 1	10	5 x10	**50**	10 x 10	**100**
	R	7, 8, 9, 11, 14		7, 8, 9, 11, 14		7, 8, 9, 11, 14, 44; 45; 58; 59; 60	
	P	16, 29, 30		11, 12, 13, 16, 18, 28, 30, 31		18, 20, 21, 55	

[a] Code = C = Knowledge and Concern, which is a summary of the degree of knowledge (where 1 = High - a subject area that is well understood (or there is a fair amount of information available), 5 = Medium - a fair amount is known about the subject and 10 = Low – the subject areas is not well understood, or there is need for more knowledge] x Degree of Concern, where 1 = a low degree of concern, 5 = a medium degree of concern, and 10 = a high degree of concern. The consequence of these rankings is found by multiplying the degree of knowledge by the degree of concern. The resulting numbers range from 1 to 100, where 100 indicates a high need for research).

R = Recommendations of the Oil Sands Wetlands Working Group - from list of recommendation in Table 7.1 of the guideline

P = Research Programs Completed - from list of completed projects, as described in Appendix K

Based on the degree of concern and the degree of knowledge, scores of 100 were recorded for the following research areas:

1. Water Chemistry
   - salinity in wetlands on CT deposits
   - water release rates of CT deposits
   - treatment capability of treatment wetlands on CT deposits
2. Biology
   - diversity in wetlands on CT deposits
   - bioaccumulation in wetlands on CT deposits
   - chronic toxicity in wetlands on CT deposits
   - chronic toxicity in wetlands on tailings sands
   - riparian areas on CT deposits
   - connector streams on CT deposits
3. Physical
   - hydrology on CT deposits
4. Traditional Land Use
   - traditional uses of wetlands on CT deposits

APPENDIX K
CONRAD RESEARCH PROJECTS

APPENDIX K: CONRAD RESEARCH PROJECTS

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#	PROJECT TITLE / CONRAD Identification Number	PROJECT OBJECTIVES / REPORT TITLES
1	Environmental Dynamics of Base/Neutral Compounds from Oil Sands Fine Tailings	To conduct research on release and environmental fate and pathways of base/neutral compounds from fine tailings in experimental systems being developed by Syncrude and Suncor for fine tailings management.
	AQ-4	Brownlee, B.G., S. Lait, R. Madill, N. Bunce, P. Fedorak, J. Lee. 1996. Environmental Dynamics of Base/Neutral Compounds from Oil Sands Fine Tailings. Phase One (1995/96) Progress Report. National Water Research Institute. Burlington Ontario. NWRI Contribution No. 96-168. 32 p.
2	Assessment of Biodegradation Rates of Radio-Labeled Naphthenic Acid Components in Tailings Pond Water under Different Environmental Conditions	Assess the impact of various environmental conditions on mineralization of naphthenic acids. Determine the fate of labeled compounds in terms of various environmental compartments, such as air, water, sediment and vegetation. Examine the effects of temperature and nutrients on the mineralization rates.
	AQ-7	Lai, J.W.S., L. Pinto, E. Kiehlmann, L.I. Bendell-Young and M.M Moore. 1995. The Mineralization of Naphthenic Acids in Oil Sands Wastewater by Indigenous Microbial Communities. Prepared for the Fine Tails Fundamentals Consortium. EVS Project No. 3/532-02. EVS Consultants.
3	Natural Biological Tailings and Seepage Water Decontamination	Further development of the understanding of the water treatment potential of constructed wetlands and water capped fine tails lakes.
	AQ-8	EVS Consultants. 1995. Constructed Wetlands for the Treatment of Oil Sands Wastewater-Technical Report #4. Prepared for Suncor Inc. O.S.G. EVS Report # 3/144-28. North Vancouver, British Columbia.
4	Bioaccumulation within Biota on Amended/ Modified Fine Tails	Laboratory investigations to evaluate the bioaccumulation of PAH and heterocyclic compounds within benthic invertebrates and macrophytes living in association with oil sands waste materials and wastewaters. Additional investigations to full characterize the acute toxicity of the tails and related waters.
	AQ-9	Golder Associates Ltd. 1996. Toxicity and Bioaccumulation Potential of Fine Tails and Tailings Water from Oil Sands Extraction. Submitted to the Alberta Oil Sands Technology and Research Authority. Golder Project No. 942-2287. Calgary, Alberta.
5	Phosphorus Dynamics in Syncrude's Experimental Pits	Study on the availability of phosphorus (a nutrient) in experimental water capped fine tails test ponds
	AQ-10	U of A report to Syncrude
6	Reclamation Landscape Model	Completion of the development of a comprehensive model designed to simulate the dynamics of contaminants within reclaimed oil sands landscapes, and to provide routines to allow contaminant fate determinations to be completed for natural environment receptor areas off the oil sands leases.
	AQ-11	Golder Associates Ltd. 1995. 1993/1994 Reclamation Landscape Model Development Project. Submitted to Suncor Inc., Oil Sands Group and Syncrude Canada Limited. Golder Project Report No. 952-2339. Calgary, Alberta.
7	Water Capping Experiments	Studies on field-scale water-capped tailings ponds at the Syncrude Canada Mildred Lake site
	AQ-12	Miscellaneous presentations, papers and summaries – See Volume II – Fine Tails and Process Water Reclamation In: Advances in Oil Sands Tailings Research – Prepared by The Fine Tailings Fundamentals Consortium. 1995. Alberta Department of Energy, Oil Sands and Research Division.

8	Natural or Managed Biological Treatment of Waters Released from the Consolidated Tails Process	Assess the treatability of Consolidated Tailings (CT) release waters to determine whether biological treatment, either natural or supplemental (i.e., additions of nutrients) is effective in pond and/or wetlands treatment systems. Treated waters which are released from these treatment areas must be suitable for release to the natural environment.
	AQ-16	EVS Environment Consultants. 1996. Constructed Wetlands for the Treatment of Oil Sands Wastewater. Technical Report #5. Prepared for Suncor Inc., Oil Sands Group. EVS Project NO. 3/144-31. North Vancouver, British Columbia.
9	Biological Treatment Options for Consolidated Tailings Release Waters	Evaluation of the biological options (i.e., wetlands or lake treatment) for the treatment of waters released from the Consolidated Tailings technology. This is a laboratory (bench-scale) study to determine whether biological or enhanced biological treatment will allow waters to be released to the environment.
	AQ-17	EVS Consultants and NOVATEC Consultants. 1995. Biological Treatment Options for Consolidated Tailings Release Waters. Prepared for Suncor Inc., Oil Sands Group. EVS Project No. 3/144-30. North Vancouver, British Columbia.
10	Baseline Aquatic Monitoring	Establishment of an environmental database which documents the chemical, toxicological and biological characteristics of: Crane Lake, a wetlands near Crane Lake, Loon Lake and the south mine drainage ditch. The results of the characterization will be reviewed and evaluated to predict possible future impacts related to channeling of oil sands wastewaters through these systems.
	AQ-18	EVS Environment Consultants. 1996. Suncor Lease 86. Baseline Aquatic Monitoring. Prepared for Suncor Inc., Oil Sands Group. EVS Project NO. 3/144-32. North Vancouver, British Columbia.
11	Laboratory Studies on Trophic Level Effects and Fish Health of Suncor Tar Island Dyke Wastewater	Derive dose-response curves pertinent to aquatic ecosystem health for selected wastewaters that will be released from oil sands operations and to characterize the chemical compounds and selected toxicological properties of the wastewaters.
	AQ-19	Golder Associates Ltd. 1996. Fish Flavour Impairment Study. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta.
12	Rainbow Trout Fish Tainting Analysis	Determine the effect, if any, on the flavour of the flesh of rainbow trout exposed to Suncor wastewater treatment system effluent, Tar Island Dyke seepage waters and the waters of the Athabasca River.
	AQ-20	Golder Associates Ltd. 1996. Laboratory Studies on Trophic Effects and Fish Health. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta.
13	Determining the Ecological Viability of Constructed Wetlands	Determine the ecological effects of effluent from the oil sands treatment process on constructed wetlands. Compare the relative health of biota currently established within wetlands that have historically received oil sands wastewaters, to that of biota within control and reference wetlands.
	AQ-21	EVS Environment Consultants. 1994. Constructed Wetlands for the Treatment of Oil Sands Wastewater. Technical Report #3. Prepared for Suncor Inc., Oil Sands Group. EVS Project NO. 3/144-26. North Vancouver, British Columbia.

14	Suncor EIA (Including the Aquatic Baseline Report for the Athabasca, Steepbank and Muskeg Rivers in the Vicinity of the Steepbank and Aurora Mines)	The primary objective of this project is to: a(establish the aquatic baseline for the Athabasca, Steepbank and Muskeg Rivers in the vicinity of the Steepbank and Aurora Mines, and b) assess the aquatic impacts associated with oil sands operations on the Athabasca and Steepbank Rivers, including water quality, benthic invertebrates and fisheries of the local Suncor study area.
	AQ-22	Golder Associates Ltd. 1996. Athabasca River Water Releases Impact Assessment. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta. Golder Associates Ltd. 1996. Aquatics Baseline Report for the Athabasca, Steepbank and Muskeg Rivers in the Vicinity of the Steepbank and Aurora Mines. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta. Golder Associates Ltd. 1996. Impact Analysis of Aquatic Issues Associated with the Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta.
15	Suncor EIA Hydrology and Hydrogeology	The primary objective of this project is to define the hydrology and hydrogeology of the Steepbank Mine development area.
	AQ-23	Golder Associates Ltd and Klohn-Crippen. 1996. Impact Analysis Steepbank Mine EIA Surface Water and Groundwater. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta. Golder Associates Ltd and Klohn-Crippen. 1996. Hydrology Baseline Steepbank Oil Sands Mine. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta. Golder Associates Ltd and Klohn-Crippen. 1996. Hydrogeology Baseline Steepbank Oil Sands Mine. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta. AGRA Earth and Environmental Ltd. 1996. Athabasca River Bridge to Steepbank Mine River Hydraulics and Ice Study. Submitted to H.A. Simons for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta.
16	Suncor EIA Environmental and Human Health Risk Assessment (CIA) Including a Reclamation Performance Assessment for Lease 86/17	Determine the ecological and human health risks associated with the oil sands operations and planned reclamation scenarios. The project will involve application of the Oil Sands Reclamation Performance Assessment Framework (OSRPAF). Which was developed jointly by Suncor and Syncrude, as one of the tools to evaluate specific and cumulative impacts.
	AQ-24	Golder Associates Ltd. 1996. Impact Analysis of Human Health Issues Associated with the Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 952-2307. Calgary, Alberta.
17	Consolidated Tailings Release Water Wetlands Study	Assess the impacts on terrestrial and aquatic plants within wetlands and dry (hummock-simulation) areas where consolidates tailings (CT) release waters area added to the typical inputs of the dyke seepage and natural runoff waters.
	AQ-25	Golder Associates Ltd. Field Scale Trials to Assess Effects of Consolidated Tails Release Water on Plants and Wetlands Ecology. Prepared for Suncor Inc., Oil Sands Group. Golder Project Report No. 962-1881. Calgary, Alberta.
18	Use of Constructed Wetlands to Treat Oil Sands Wastewaters	Evaluation of wetlands plant community structure on and off the Suncor site and establishment of baseline reference values for the physiological makers used to evaluate fish health. The 1996 project is designed to provide baseline information for a planned 1997/98 project supported through an Industrial Oriented Research grant through NSERC and ESTAC (Environmental Science and Technology Alliance of Canada).
	AQ-26	Bendell-Young, L.I., A.P. Farrell, C. Kennedy, M.M. Moore, A.L. Plant and T. Williams 1997. Assessing the Ecological Viability of Wetlands for Treatment of Oil Sands Wastewaters, A Feasibility Study. Prepared for Suncor Inc., Oil Sands Group. Simon Fraser University. Vancouver, BC.

19	Laboratory Study on Trophic Level Effects and Fish Health Effects of Suncor's Wastewater Treatment System Discharge	Evaluate a variety of effects and health of fish exposed to Suncor's Wastewater Treatment System discharge through exposure of fish within a laboratory set-up. The study will include trophic effects assessment, fish health effects, challenge tests, chemical characterization of the wastewater and tissue residues, and evaluation of the tainting potential.
	AQ-27	HydroQual. 1996. Laboratory Studies on Trophic Level Effects and Fish Health Effects of Suncor Tar Island Dyke Wastewater. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.
20	Salt Tolerance Study	Assess impacts of consolidated tailings (CT) release waters on typical oil sands reclamation plant species using a green house hydroponics set-up.
	AQ-28	Renault, S., J. Zwiazek. 1997. Salt tolerance of plants treated with Consolidated Tailings Water. Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Limited. University of Alberta. Edmonton, Alberta.
21	Preliminary Studies on Immune Function Assays in Tree Swallows and Mallard Ducks	Development of immune function assays which can be applied to the planned 1997/98 ESTAC study to determine the ecological characteristics and long-term ecological viability of constructed wetlands receiving effluent from the oil sands process. The development of these assays will provide a non-lethal test of one aspect of immune functions in passerine birds. The work on Mallard ducks will evaluate the possibilities of conducting immune response analyses on blood collected from live birds, frozen and then evaluated in a laboratory.
	AQ-29	Smits, J., K. Liber, C. Zimmer and M. Wayland. 1997. Impacts of wetland contaminants on Tree Swallows and Mallard Ducks. Oil Sands Reclamation Studies – Year 1 Annual Report, Toxicology Center, University of Saskatchewan. 40 pp.
22	Suncor EIA Air	Evaluation of the local and regional impacts associated with air emissions for the current and proposed Suncor operation.
	AT-12	Bovar Environmental and Golder Associates Ltd. 1996. Impact Analysis of Air Emissions Associated with the Steepbank Mine. Prepared for Suncor Inc. Oil Sands Group. Bovar Environmental. 1996. Sources of Atmospheric Emissions in the Athabasca Oil Sands Region. Prepared for Suncor Inc. Oil Sands Group and Syncrude Canada Ltd. Bovar Environmental. 1996. Ambient Air Quality Observations in the Athabasca Oil Sands Region. Prepared for Suncor Inc. Oil Sands Group and Syncrude Canada Ltd. Bovar Environmental. 1996. Meteorology Observations in the Athabasca Oil Sands Region. Prepared for Suncor Inc. Oil Sands Group and Syncrude Canada Ltd. Bovar Environmental. 1996. Ambient Air Quality Predictions in the Athabasca Oil Sands Region. Prepared for Suncor Inc. Oil Sands Group and Syncrude Canada Ltd.
23	Dewatering Fine Tails by Evaporation	This project is designed to evaluate alternate methods of dewatering fine tailings, with the focus on the use of evaporation through maximization of surface exposures.
	TE-6	Li, X., Y. Feng. 1995. Dewatering Fine Tails by Evaporation: A Mathematical Modelling Approach. Prepared for Syncrude Canada Ltd. University of Alberta, Edmonton, Alberta.
24	Phytotoxicity of Reclaimed Fine Tails and Tailings Sands	This project has four primary objectives, including to :a) determine the extent of uptake and distribution in woody plants of the organic components of fine tails, consolidated (non-segregating) tails and tailings sands present in various soil profiles; b) examine the extent to which these components are metabolized in plants; c) determine the phytotoxicity of these components on different woody plant species; and d) determine the mechanism of their phytotoxicity.
	TE-10	Renault, S., J. Zwiazek. 1997 Phytotoxicity of Reclaimed Fine Tails and Tailings Sand – Annual Report 1995/1996. Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Limited. University of Alberta. Edmonton, Alberta.

25	Effect of Oil Sands Tailings on Plant Growth	Continuation of Project TE-10
	TE-10b	Renault, S., J. Zwiazek. 1997. Effects of CT Materials on Plants. Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Limited. University of Alberta. Edmonton, Alberta.
26	Dewatering and Contaminant Uptake by Plants from Oil Sands Tailings	This project has three primary objectives, including the: a) determination of the capability of plants to facilitate the dewatering of the surface and subsurface of various types of oil sands tailings; b) study of the uptake of contaminants by plants growing on the various types of tailings; and c) evaluate the health of, and uptake of contaminants by plants growing on reclaimed oil sands tailings areas.
	TE-11	Alberta Environmental Centre. 1996. Plant Growth, Dewatering and Metal Uptake from Oil Sands Fine Tails and Tailings. Edited by J.J. Xu. Prepared for Suncor Inc., Oil Sands Group. Vegreville, Alberta.
27	Dewatering and Contaminant Uptake by Plants from Oil Sands Tailings	Continuation of Project TE-11
	TE-11b	Alberta Environmental Centre. 1997. Plant Growth and Metal Uptake from Oil Sands Fine Tails and Tailings. Prepared for Suncor Inc., Oil Sands Group. Vegreville, Alberta.
28	Erosional Resistance of Reclaimed Tailing Sand Structure	The primary objective of this project is to determine sand slope erosion potentials based on variations in rainfall and surface cover. The study will include the determination of the response of different areas of the reclaimed surface of tar Island Dyke (TID) and Syncrude's tailings sand dykes respond to various intensities of rainfall, including 1 in 10, 1 in 100 and 1 in 1000 year events. The study will also include and evaluation of rainfall events of an area of TID which will be burned to simulate a forest fire event. Coupled with the study of erosion potentials is a detailed evaluation of the plant growth and soil conditions on the surface of TIS (separate CONRAD project – Te-15).
	TE-12	AGRA Earth and Environment. 1996. Erosion Resistance of Suncor's Reclaimed Sand Structures. Submitted to Suncor Inc., Oil Sands Group. Calgary, Alberta.
30	Suncor EIA Wildlife	Describe the use of the Suncor local study area by wildlife, including any rare and endangered species. Evaluate wildlife habitat, its availability and any seasonal usage. For key wildlife species determine usage within the area and evaluate the potential impacts of the proposed Steepbank Mine project on these species.
	TE-16	Westworth, Brusnyk and Associates and Golder Associates Ltd. 1996. Impact Analysis Suncor Steepbank Mine EIA Wildlife Component. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Westworth, Brusnyk. 1996. Abundance and Distribution of Moose and other Mammals in the Suncor Study Area. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Westworth, Brusnyk. 1996. Habitat Suitability Models for the Suncor Study Area. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Westworth, Brusnyk. 1996. Herpetofauna in the Steepbank Study Area. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Westworth, Brusnyk. 1996. Waterfowl, Raptors and Breeding Terrestrial Birds of the Suncor Lease in 1995. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Westworth, Brusnyk. 1996. Baseline Study for Fur Trapping in the Suncor Study Area. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

31	Suncor EIA Biophysical (Soils, Vegetation and Terrain)	Detail the soil, vegetation and terrain (biophysical) components of the proposed Steepbank Mine development area. Evaluate the impact of the development of the Steepbank Mine on these components, both from a local and regional area basis. The information is available to develop the conservation and reclamation plan for the new development.
	TE-17	Can-Ag Enterprises. 1996. Baseline Soil Survey for the Proposed Suncor Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Golder Associates Ltd. 1996. Impact Analysis of Terrestrial Resources Associated with the Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. EnviResource Consulting Ltd. and Golder Associates Ltd. 1996. Suncor Inc. Mine Expansion: Baseline Forestry Report. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Golder Associates Ltd. 1996. Terrestrial Baseline Report for the Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Golder Associates Ltd. 1996. Visual Impact of Suncor Steepbank Mine Development. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta. Golder Associates Ltd. 1996. Suncor Mine Advance Plan (D&R) and Cumulative Effects Assessment. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.
32	Field-Scale Trials to Assess Effects of Consolidated Tailings Release Water on Plants and Wetlands Ecology	Assess the effects of Consolidated Tailings (CT) release water on plants and wetlands ecology to provide an input for CT reclamation planning. This project will increase the understanding of the environmental impacts associated with CT and how best to construct and maintain a CT reclamation landscape.
	EN-97-01	Golder Associates Ltd. 1997. Field Scale Trials to Assess Effects of Consolidated Tails Release Water on Plants and Wetlands Ecology. Submitted to Suncor Energy Inc., Oil Sands.
33	Field-Scale Trials to Assess Effects of Consolidated Tailings Release Water on Plants and Wetlands Ecology	Continuation of EN-97-01
	EN-98-14	Report to be released in March 1999.
34	Impact of CT Release Water on Wetlands Chironomids	Assess the effects of Consolidated Tailings (CT) release water on chironomids to evaluate using them as a monitoring tool for assessing the viability of wetlands receiving CT release water (i.e., CT reclamation landscape).
	EN-97-02	Ciborowski, J. and M. Whelly. 1997. Chironomidae as Indicators of Wetland Viability: Report on Field Work in Wetlands of the Fort McMurray Alberta Area. Technical Report No. 4. University of Windsor. Windsor Ontario.
35	Impact of CT Release Water on Wetlands Chironomids	Continuation of EN-97-02
	EN-98-13	Whelly, M.P., J.H. Ciborowski, C. Leonhardt and D. Laing. 1998. Chironomidae as indicators of wetland viability: report on field work in wetlands in Fort McMurray, Alberta area (Jun 12-July 16, 1998). Prepared for Suncor Energy Inc., Oil Sands by University of Windsor. 73 pp.
36	Effects of CT Deposits and Release Water on Plants	Assess the effects of Consolidated Tailings (CT) release water on plants to provide a plant prescription for the CT reclamation areas. This project will increase the understanding of CT effects on plants, which plants are best suited for CT reclamation landscape and why.
	EN-97-03	Golder Associates Ltd. 1997. Field Scale Trials to Assess Effects of Consolidated Tails Release Water on Plants and Wetlands Ecology. Submitted to Suncor Energy Inc., Oil Sands.

37	Effects of CT Deposits and Release Water on Plants	Continuation of EN-97-03
	EN-98-10	Report to be issued in March 1999
38	Ecological Viability of Wetlands Receiving Consolidated Tailings Release Water	Assess the effects of Consolidated Tailings (CT) release water on the ecological viability of wetlands receiving the wastewater. This project will increase the understanding of environmental impacts associated with CT and how best to construct maintain a CT reclamation landscape by identifying CT tolerant/intolerant species.
	EN-97-04 (Continuation of AQ-26)	Bendell-Young, L.I., A.P. Farrell, C. Kennedy, M.M. Moore, A.L. Plant and T. Williams 1997. Assessing the ecological characteristics of wetlands receiving oil sands effluents: final report for the 1997 field season. Prepared for Suncor Inc., Oil Sands Group by Simon Fraser University. Vancouver, BC.
39	Ecological Viability of Wetlands Receiving Consolidated Tailings Release Water	Continuation of EN-97-04
	EN-98-12	Bendell-Young, L.I., H. Ban, K. Bennett, W. Challanger, A. Crowe, A.P. Farrell, A. Kermode, A. Kolok, A.L. Plant, I. Pollet, J. Tang and T. Williams 1998. Ecological characteristics of wetlands receiving oil sands effluent: final report for the 1998 field season. A collaborative project at Simon Fraser University. Prepared for Suncor Inc., Oil Sands Group. Simon Fraser University. Vancouver, BC. Schley, P., L. Pinto and M. Moore. 1998. Biodegradation of Naphthenic Acids in Sediments Receiving Oil Sands Wastewater. Prepared for Suncor Energy Inc., Oil Sands by Department of Biological Sciences, Simon Fraser University.
40	Impact of CT Release Water on Tree Swallows and Mallards	Assess the biological impacts on local bird populations which frequent wetlands receiving CT release water.
	EN-98-11	Smits, J., M. Miller, C. Zimmer and M. Wayland. 1998. Impacts of wetland contaminants on Tree Swallows and Mallard Ducks. Prepared for Suncor Energy Inc., Oil Sands and Syncrude Canada Ltd. by University of Saskatchewan.
41	Impacts of Process Affected Waters on Zooplankton Ecology	To assess the affect of process affected waters on the quantity and taxonomy (diversity) of Zooplankton; and determine threshold concentrations where process related components cause an impact.
	EN-98-15	
42	Impacts of Process Affected Waters on Phytoplankton Ecology	To assess the affect of process affected waters on the quantity and taxonomy (diversity) of Phytoplankton; and determine threshold concentrations where process related components cause an impact.
	EN-98-16	Report to be completed in 1999
43	Analysis and Assessment of Plankton Data Collected from Experimental Ponds on the Syncrude Canada Ltd. Lease	To assess the data describing plankton (both zoo and phytoplankton) communities that have been established in various waterbodies in Syncrude's Lease 17 and 22.
	EN-98-17	Report to be completed in 1999
44	The Effect of Sediment on the Growth of Aquatic Plants in the Littoral Zone of a Constructed Lake	To determine the success of aquatic plant growth, based exclusively on the type of substrate (various reclamation materials).
	EN-98-18	Report to be completed in 1999
45	Modelling Observed Toxicity Responses to Syncrude Fine Tailings Exposure in Yellow Perch	To utilize the field data to construct a population model of perch of waterbodies at Syncrude's Lease 17/22.
	EN-98-19	Report to be completed in 1999
46	Salt Sensitivity of Jack Pine Seedlings, and a Test of Culling as a Method of Producing Salt Tolerant Seedlings	To assess the sensitivities of Jack Pine to salts derived from CT and other process affected waters.
	EN-98-20	Report to be completed in 1999

47	Effect of Salt and CT Release Water on Conifer Germination	To assess the impact of saline waters and CT produced waters on the germination and early growth of trees native to the boreal forest
	EN-98-21	Report to be completed in 1999
48	Toxicity of Base Neutral Compounds from Oil Sands Derived Fine Tails	To characterize the PACs (polyaromatic compounds) in fine tailings porewaters and determine their acute and genotoxicity of solubalized PACs.
	EN-98-22	Project currently in progress.
49	Mammalian Toxicity Associated with Naphthenic Acids	To assess the acute, chronic and sub-chronic effects of naphthenic acids on mammals.
	EN-98-23	3-yr study initiated in 1997
50	Evaluation of ESIMS as a Technique for Analysis of Naphthenic Acids	Assess the application of ElectroSpray Ionization Mass Spectrometry (ESIMS) for qualitative and quantitative analysis of naphthenic acids.
	EN-98-24	Project currently in progress.
51	Genotoxicty Testing: Examination of Red Blood Cells for DNA Damage of Selected Perch Populations	To assess the use of the application of cytometry to detect genetic damage (DNA) in perch populations collected from various waterbodies including the Mildred Lake (Raw Water Intake), South Bison Pond and Water Capped Demo Pond.
	EN-98-25	Report to be completed in 1999.
52	The Effect of Tailings Pond Water on the Response of Fathead Minnows (*Pimephales promelas*) to Food Stimuli	To assess the effect of tailings pond water on the ability of fathead minnows to find food (one of the sub-lethal behavioural affects that process affected waters may impose on resident fish).
	EN-98-26	Report to be completed in 1999
53	Effect of Syncrude Oil Sands Process Water on Chemically Mediated Assessment of Predation Risk by Fathead Minnows (*Pimephales promelas)*	To assess the effect of chemical constituents of oil sands process affected water on the ability of fathead minnows to detect predators (one of the sub-lethal behavioural affects that process affected waters may impose on resident fish).
	EN-98-27	Report to be completed in 1999
54	Effects of Tailings Water on Chemosensory Cues Regulating Key Behavioral and Physiological Processes on Fishes	To assess the effects of Syncrude's tailings pond water on olfactory-dependent processes in fish. In addition, also assess the impairment due to long term establishment, or short term maintenance of fish populations in waterbodies in contact with tailings.
	EN-98-28	Report to be completed in 1999
55	Oil Sands CT Water Fish Health and Fish Tainting Study	To evaluate the potential of chemicals within oil sands CT water to impact the health of fish within receiving water areas, as well as to evaluate whether CT waters can result in tainting of the flesh of fish.
	EN-99-01	Project currently in progress.
56	Assessment of the Natural and Anthropogenic Impacts of Oil Sands Contaminants within the Northern River Basin	To coordinate program activities and provide a synthesis and integration report for a number of projects under the assess the potential environmental sensitivities of aquatic systems to long-range transport of bitumen-enriched material associated with the expansion of oil sands developments in northeastern Alberta.
	EN-99-02	Project currently in progress.
57	Chemistry and Ecotoxicology of Organic Compounds in Bitumen Froth Relating to Long-Range Transport in Oil Sands Operations	To assess the potential environmental sensitivities of aquatic systems to long-range transport of bitumen-enriched material associated with the expansion of oil sands developments in northeastern Alberta.
	EN-99-	Project currently in progress.
58	Ecological Effects of Natural Versus Anthropogenic Releases of Oil Sands Contaminants	The project objectives are to: 1. Determine the fate of natural versus anthropogenically derived polycyclic aromatic hydrocarbons (PAHs) in riverine food webs; 2. Quantify the entry of PAHs into riverine food webs and the potential for trophic transfer of the se contaminants; and 3. Development and validation of field-based sublethal toxicity tests and bioassessment methods to determine the effects of oil sands contaminants on benthic indicators.
	EN-99-	Project currently in progress.

59	Use of Mesocosms to Assess Ecological Risk Associated with Exposure to Natural and Anthropogenic Oil Sands Contaminants	The project objectives are to: 1. Determine the ecological responses of fish and lower trophic levels to oil sands contaminants under field-based, dose-response conditions; 2. evaluate current and newly developed sublethal toxicity tests for application to the oil sands industry; and 3. Confirm and strengthen conclusions from fields studies by providing cause-effect results of future effluent release scenarios.
	EN-99-	Project currently in progress.
60	Long-Range Transport of Hydrocarbons to the Northern Deltas and Lakes; Pathways and Fate	To assess the spatial patterns in hydrocarbon concentrations and composition downstream from the Suncor/Syncrude oil sands developments including the Peace-Athabasca delta lakes and Lake Athabasca.
	EN-99-	Project currently in progress.
61	Identification and Characterization of Natural Hydrocarbon Release from Oil Sands Deposits in the Northern River Basins Area	To provide an improved understanding of the spatial distribution, nature and extent of natural hydrocarbon releases to the environment within the oil sands region and to identify biotic communities most at risk from such releases.
	EN-99-	Project currently in progress.
62	Assessment of the Effects of Naturally Occurring Polycyclic Aromatic Hydrocarbons (PAH) Associated with Alberta Oil Sands	To assist industry and regulators in discriminating between potential effects related to natural versus anthropogenically derived polycyclic aromatic hydrocarbons (PAHs)
	EN-99-	Project currently in progress.
63	Investigation of the Environmental Effects of Oil Sands Refinery Effluents	To evaluate the suitability of current aquatic toxicity tests and a suite of new sublethal tests for potential use in an Environmental Effects Monitoring program (EEM) for oil sands effluents and, if necessary, develop alternative biological tests to predict the ecological effects of these effluents; and to identify the chemicals responsible for any environmental impacts related oil sands refinery effluents.
	EN-99-	Project currently in progress.
64	The Ecological Viability of Constructed Wetlands at Suncor: Population and Health-Related Considerations in Birds and Amphibians	To develop and field-validate a sensitive, ecologically-relevant approach using immune response which can be used as an early warning system of adverse environmental effects produced by oil sands tailings and effluents
	EN-99-	Project currently in progress.