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Interpretation guide of natural geographic features from ETM+ Landsat imagery and aerial photography: Wetlands (marshes, swamps, and peat bogs)

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Introduction

The purpose of this project is to create a visual interpretative guide to the natural geographical entities in the geospatial database (GDB) using Landsat7 ETM+ imagery and aerial photography. The methodology and information fact sheet were developed by Provencher and Dubois (2004a), and the application of this procedure to a test case has already garnered a consensus among the staff of CTI at Sherbrooke (Provencher and Dubois (2004b). The meanings of the sections of the fact sheets are explained in the appendix.

The eight natural entities in the GDB (Centre for Topographic Information, 2004) fall under eight themes that are grouped into three domains: hydrography, landforms, and vegetation (**Table 1**). In practice, for interpretive purposes they are often subdivided further and represented by 17 fact sheets.

N.B.: Elaboration of the illustrative examples and potential elements of confusion was constrained by the limited time allocated to this guide. It is recommended that they be supplemented as other cases are documented, especially from Landsat ETM+ imagery.

Table 1: Hierarchy of natural geographical entities

Domain	**Theme**	**Sub-theme**	**GDB entity**	**Fact sheet**
Hydrography	Watercourse	Perennial watercourse	Permanent water	Permanent water
		Alluvium	Intermittent water	Intermittent water
		Waterfall	Water disturbance	Waterfalls and rapids
		Rapids	Water disturbance	Waterfalls and rapids
	Waterbody	Perennial freshwater body	Permanent water	Permanent water
		Alluvium, rocky surface	Intermittent water	Intermittent water
		Saltwater	Permanent water	Permanent water
		Alluvium, rocky surface (tidal flat)	Intermittent water	Intermittent water
		Reef	Water disturbance	Reef
	Wetland	Tundra pond	Saturated soil	Tundra ponds
		Palsa bog	Saturated soil	Palsa bog
		Marsh, swamp, and uniform peat bog (wetland)	Saturated soil	Wetlands (marshes and swamps, peat bogs
		String bog	Saturated soil	Wetlands (string bog)
Landforms	Glacial landform	Glacial debris	Landform	Glacial debris
		Esker	Landform	Esker
		Moraine	Landform	Moraine
		Glacier, glacial ice cap, and ice shelf	Permanent snow and ice	Permanent snow and ice
	Periglacial landform	Polygonal soil	Landform	Tundra polygon
		Pingo	Landform	Pingo
	Littoral landform	Barrier beach and spit	Landform (sand)	Barrier beach and spit
	Eolian landform	Dunes	Landform (sand)	Dunes
Vegetation	Wooded region		Wooded region	Wooded region

1- Name of entity

Marshes and swamps

2- Hierarchy

Hydrography – saturated soil – wetlands (marshes, swamps, and peat bogs)

3- Definition

Wetlands: a sector harbouring plants requiring large amounts water. This vegetation may grow within water, on land that is intermittently submerged, or on land that is merely poorly drained and saturated with water. The flora depends on the degree of hydromorphism of the soil: reeds, rushes, water plants, shrubs, trees, etc. (CTI, 2004). To CTI, "wetlands" is a generic term encompassing all the moist environments listed hereafter:

Marsh; a treeless and saturated sector of poorly drained soil that is temporarily or permanently submerged and features aquatic or herbaceous vegetation no more than two metres high (CTI, 2004).

According to Buteau et al. (1994), marshes are permanently, intermittently, or sporadically submerged wetlands with a substrate that is saturated and under water during most of the growing season. The plant cover is characterized by emergent hydrophilic herbaceous vegetation (Figures 1 and 2).

Marsh in Water: a sector in the water with cattails and aquatic vegetation on or above the water's surface (CTI, 2004).

Swamp: A saturated sector, intermittently or permanently under water, with woody and shrubby vegetation exceeding two meters in height and covering over 35 percent of the area (CTI, 2004).

According to Buteau et al. (1994), swamps are wetlands dominated by woody and shrubby vegetation growing in mineral or organic soil that is subject to seasonal flooding or characterized by a high water table and a circulation of water rich in dissolved minerals (Figure 4).

Peat bog: a former lake that is totally or partly filled in with peat. The plant cover consists of sphagnum moss, lichen, and heath (Figure 6).

Older topographic maps also depicted **muskeg**, a boggy, poorly drained, moist, spongy, and barren or sparsely wooded sector found mostly in northern Canada (CTI, 2004).

Fen: a moist environment that is watered by precipitation and waters enriched by contact with surrounding mineral soils. The plant cover is dominated by herbaceous plants and mosses, generally not sphagnum moss (Buteau et al., 1994).

Ombrotrophic bog: a moist environment that is exclusively watered by precipitation. It is a very acidic habitat in which the plant cover is dominated by sphagnum, lichen, and several type of heath (Buteau et al., 1994).

4- Summary table of elements of identification of marshes, swamps, and peat bogs

Table 2: Summary table of elements of identification of marshes

Shape	View from top: band of variable width View from side: flat profile
Dimensions	Width: decametres Length: decametres to kilometres Height: flat
Topographic position	Edge of waterbodies and watercourses
Drainage	Exposed section: poor Submerged section: not applicable

Vegetation	Exposed section: Hydrophilic herbaceous vegetation Submerged section: Floating and emergent aquatic vegetation
Emplacement process	Draining or flooding of the relief
State	Relatively stable in lacustrine and fluvial environments; in marine environments, possibility of disappearing in the Maritime Provinces and appearing in the north of the country; may be disturbed by human activity
Spatio-temporal variations	Seasonal variations in the appearances of marshes, potential for erosion in marine environments (decadal)
Environment	Edge of watercourses and waterbodies
Identification on imagery	Exposed section: bands 4-3-2 Submerged section: bands 4-3-2 and band 5
Identification with B/W aerial photography	Exposed section: pale grey hue and smooth text of vegetation Submerged section: variable hue and random structure depending on the distribution of vegetation
Elements of confusion	Permanent water, intermittent water, peat bog, beaver pond

Table 3: Summary table of elements of identification of swamps

Shape	View from top: surface more or less regular View from side: flat profile
Dimensions	Diameter: decametres to kilometres Height: flat
Topographic position	Slope benches and bottoms
Drainage	Poor
Vegetation	Shrubs and trees (coniferous and mixed)
Emplacement process	Height of the water table
State	Stable as long as the water table remains high
Spatio-temporal variations	None in the short and medium term
Environment	All environments in which hydromorphic benches are found
Identification on imagery	bands 4-3-2
Identification with B/W aerial photography	Level topography Texture from coarse to smooth (vegetation) Hue from pale grey to dark grey (vegetation)
Elements of confusion	Vegetation, intermittent water, abandoned beaver ponds

Table 4: Summary of identifying elements for peat bogs

Shape	View from top: surface more or less regular View from side: may be slightly domed in the centre (ombrotrophic bog)
Dimensions	Diameter: a few decametres to a few kilometres Height: metres
Topographic position	All topographic positions (interfluve, hillside bench, valley bottom)
Drainage	Poor
Vegetation	Herbaceous (moss, lichen, heath)
Emplacement process	Filling in of a lake basin with organic deposits
State	Stable in the medium or long term, unless drained or mined by humans
Spatio-temporal variations	None in the timeframe of human observation, unless drained or mined by humans
Environment	Throughout Canada, especially in northern regions of permafrost
Identification on imagery	Bands 4-3-2 and band 5
Identification with B/W aerial photography	Flat relief, uniform pale-grey hue, smooth texture
Elements of confusion	Marsh, string bog

5- Characteristics

5.1.- Specific to the entity

5.1.1- Shape

A) Marsh

View from top: usually a narrow and elongated strip at the edge of permanent water.
View from side: flat profile.

B) Swamp

View from top: flat and irregular, but often round or lobed.
View from side: flat profile.

C) Peat bog

View from top: irregular, most commonly lobed
View from side: generally level in the case of fens, but ombrotrophic bogs are sometimes slightly domed toward the centre.

5.1.2- Dimensions

A) Marsh

Length: a few metres to a few kilometres
Width: a few metres to a few hundred metres.
Height: nil.

B) Swamp

Diameter: a few metres to several hundred metres.
Height: flat.

C) Peat bog

Diameter: a few metres to several hundred metres.
Height: generally flat, possibly a few metres elevation toward the centre of ombrotrophic bogs.

5.1.3- Topographic position

A) Marsh

Freshwater marshes are generally found between shallow water and swamps or peat bogs in fluvial or lacustrine environments. They are also located above the high tide mark in coastal environments.

B) Swamp

Swamps often occupy a section of the floodplains bordering watercourses. They also occur on bordering benches in lacustrine and marine environments as well as on slope benches or bottoms when the water table is near the surface.

C) Peat bog

Peat bogs occupy topographic depressions (former lakes or river banks) filled with vegetation.

5.1.4- Drainage

A) Marsh

Marshes are generally flooded on a permanent basis. On rare occasions when the water level falls, the exposed surface remains moist because of its location adjacent to water.

B) Swamp

Swamps are characterized by very poor drainage, to the point of becoming completely inundated during periods of spring flooding or abundant rain.

C) Peat bog

Peat bogs are characterized by very poor drainage in a topographic depression.

5.1.5- Vegetation

A) Marsh

The vegetation of marshes consists of emergent herbaceous hydrophilic plants. This vegetation progressively protrudes from the water as of the beginning of the growing season in spring, reaching its maximum height and density in mid-summer. At that time it may cover the entire surface of the water.

B) Swamp

Swamps are colonized by woody and shrubby vegetation. The species best adapted to the hydromorphic conditions of the swamp are primarily coniferous, such as cedar, fir, black spruce, and larch. Some broadleaf species, such as alder, willow, and black ash also thrive in this environment. The height and density of the flora of the swamp are comparable to those of the neighbouring dry areas.

C) Peat bog

The vegetation of peat bogs depends on the type of water supply it receives. In the case of peat bogs fed solely by precipitation (ombrotrophic bogs), the plant cover is dominated by sphagnum moss, lichen, and heath. Peat bogs fed from both precipitation and water enriched by contact with mineral soils (fens) are principally covered by herbaceous plants and mosses.

5.2.- Relative to the entity’s dynamics

5.2.1- Emplacement process

A) Marsh

Marshes develop progressively with the encroachment of aquatic vegetation on the edges of coastal, lagoonal, estuarine, lacustrine, or fluvial ecosystems.

B) Swamp

Swamps result from a high water table in a terrestrial environment. Consequently, it is difficult to identify any

specific emplacement process, since swamps come into being when a surface satisfies the conditions described above.

C) Peat bog

Peat bogs come into being as lake basins fill in, from the periphery toward the centre, with plant matter that accumulates over the years without decaying into organic materials because the regional climate is sufficiently cold to impede this process.

5.2.2- State

A) Marsh

Marshes are relatively stable in the human timeframe—a state of transition between a surface of open water and its filling in by organic matter that is decomposed (organic materials) and fibric (peat), and trapped sediments. The edges of marshes in coastal environments are subject to the erosive action of storm swells. In inhabited regions, marshes are often disturbed by human activities (encroachment).

B) Swamp

Swamps are inherited formations that are unlikely to change in the short or medium term. Only a fall or rise in the level of the water table, whether natural or induced, can cause the transformation of a swamp. In inhabited regions, swamps are often drained to increase their productivity for agriculture or forestry.

C) Peat bog

The peat bog is an inherited formation in Canada's temperate, southern regions. In more northerly regions of permafrost it is a dynamic form. In inhabited regions, peat bogs are sometimes drained or mined (sphagnum peat).

5.2.3- Spatio-temporal variations

A) Marsh

Marshes are subject to water level fluctuations in their environment. Their appearance varies with the presence or absence of the vegetation that emerges slowly during the growing season. In coastal environments, marshes are exposed to slow erosion (decadal scale) along their edges during high tides and storms. They are also subject to human encroachment.

B) Swamp

The swamp is a stable ecosystem. It is vulnerable to shifts in the level of the water table caused by variations in rainfall, and may even be inundated during periods of flooding or after torrential rains. It may also be altered by draining or recovery actions.

C) Peat bog

The peat bog is a slowly evolving environment. It requires hundreds, or even thousands, of years before occupying the entire lakebed. It may also be modified by human activity (draining, mining).

5.3.- Relative to the environment

A) Marsh

Marshes essentially occupy the edges of water surfaces.

B) Swamp

Swamps are found on hillside benches or valley bottoms in areas where the water table is near the surface.

C) Peat bog

Peat bogs can be found in all environments that either were, or are, periglacial. Thus, they occur throughout in Canada.

6- Optimal conditions for identification

A) Marsh

With aerial photography, differences in the hue of the vegetation allow regions of high marsh to be distinguished from neighbouring zones of terrestrial or swampy plant life. They may be difficult to correctly identify if they include a low-lying area affected by tides. This part of the marsh, the mudflat, may be confused with a zone of intermittent water (alluvium). The marsh, with its smooth texture and pale-grey hue, can be mistaken for barren sediments.

With ETM+ imagery, the vegetation of the marsh can be identified and distinguished from neighbouring vegetation using bands 4-3-2. Sectors subject to water level fluctuations are harder to identify, since they can be confused with intermittent water (alluvium).

B) Swamp

It is not always easy to distinguish between swamps and the bordering wooded areas using aerial photography. Since the swamp is also covered by woody and shrubby vegetation, there is considerable potential for confusion. Ultimately, the topographic position and geomorphic context are the most useful features for distinguishing between dry and moist environments. Sometimes it may be possible to detect water between the trees and shrubs if the surface is not completely concealed by the canopy.

With ETM+ imagery, the vegetation of the swamp may be virtually indistinguishable from that of adjacent areas, since their spectral response on bands 4-3-2 is comparable. However, in some cases band 5 may prove useful for highlighting swampy zones because of their humidity.

C) Peat bog

With aerial photography peat bogs are easily distinguished from bordering ecosystems. The uniform and flat quality of the surface, the pale grey hue of the vegetation, the smooth and homogenous texture, and the way they contrast with adjacent zones all lend an easy recognizability to the peat bog.

With ETM+ imagery, peat bogs are also readily identified using bands 4-3-2, which highlight the characteristics of the vegetation, and band 5, which captures surface humidity.

7- Examples

Source : Buteau *et al.* (1994)

Figure 1 : Example of a high freshwater marsh

Source : Buteau *et al.* (1994)

Figure 2 : Example of a low freshwater marsh

Source : Le Québec en images, photo 16918,

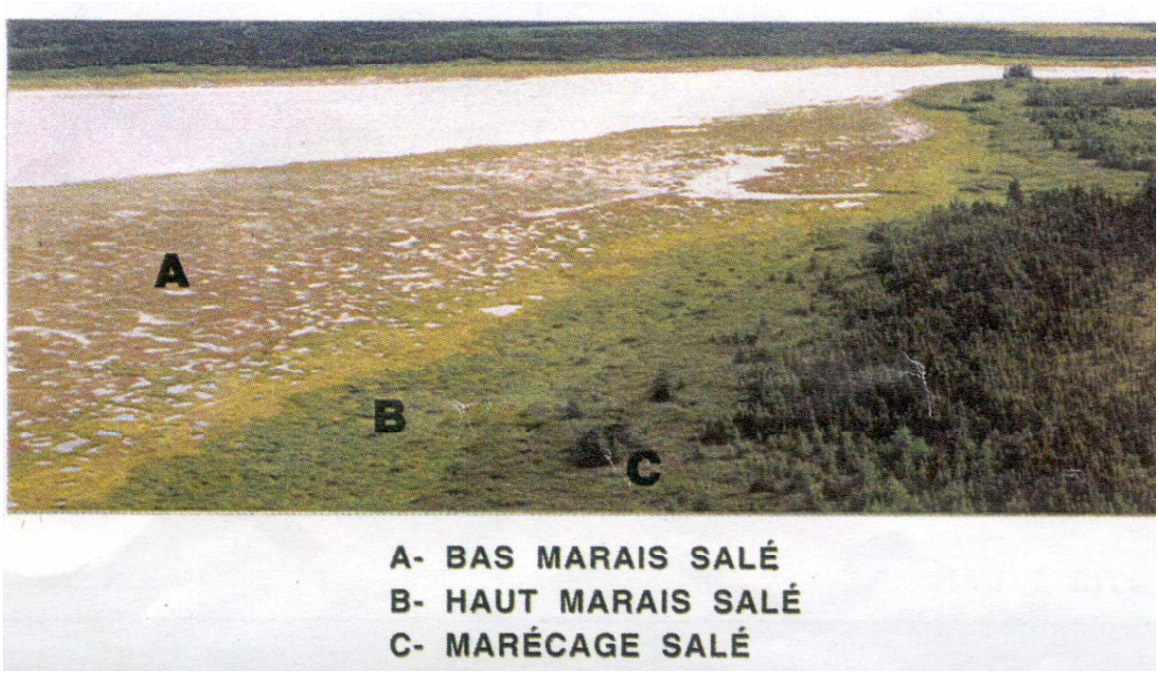
Figure 3 : Example of freshwater marsh vegetation

Source : Dubois, J.-M., (90-12-27), Îles-de-la-Madeleine

Figure 4 : Example of an erosion slope bordering a marshy lagoon

Source : Buteau *et al.* (1994)

Figure 5 : Example of a freshwater swamp

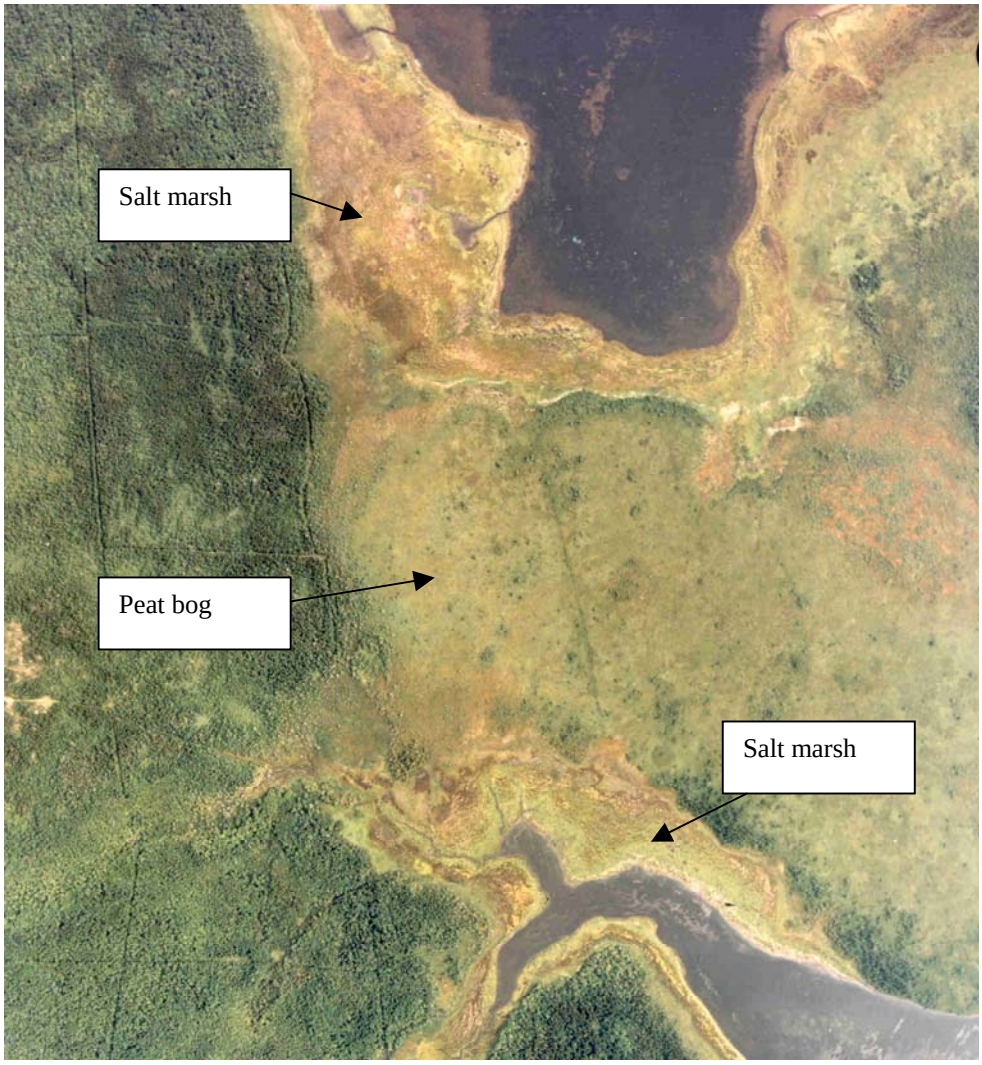


Source : Buteau *et al.* (1994)

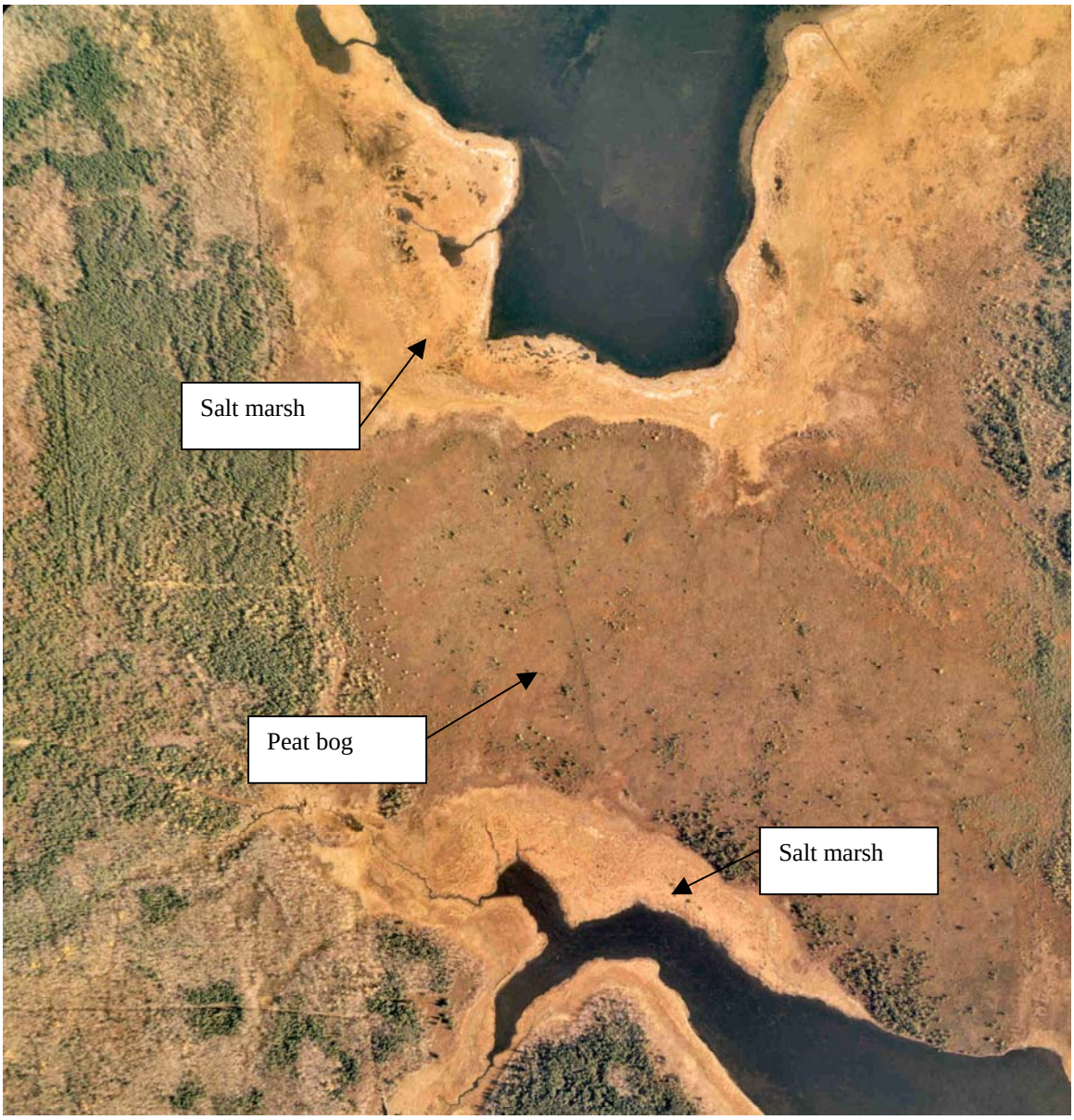
Figure 6 : Example of a coastal marsh and swamp

Source : Buteau *et al.* (1994)

Figure 7 : Example of a peat bog in a fluvial environment



A) Source : A31596 (34), Original scale 1 : 10 000, **Kouchibouguac** National Park. du 02-09-1991



B) Source: A31728 (117), original scale 1:10,000, **Kouchibouguac** National Park, 1995/10/26

Figure 8: Example of a coastal salt marsh and peat bog from photographs taken at different times. A) Distinction and delimitation between the marsh and the peat bog difficult in September, near the end of the growing period. B) Distinction and delimitation easy because of the difference in the appearance of plant life, especially in the marsh.

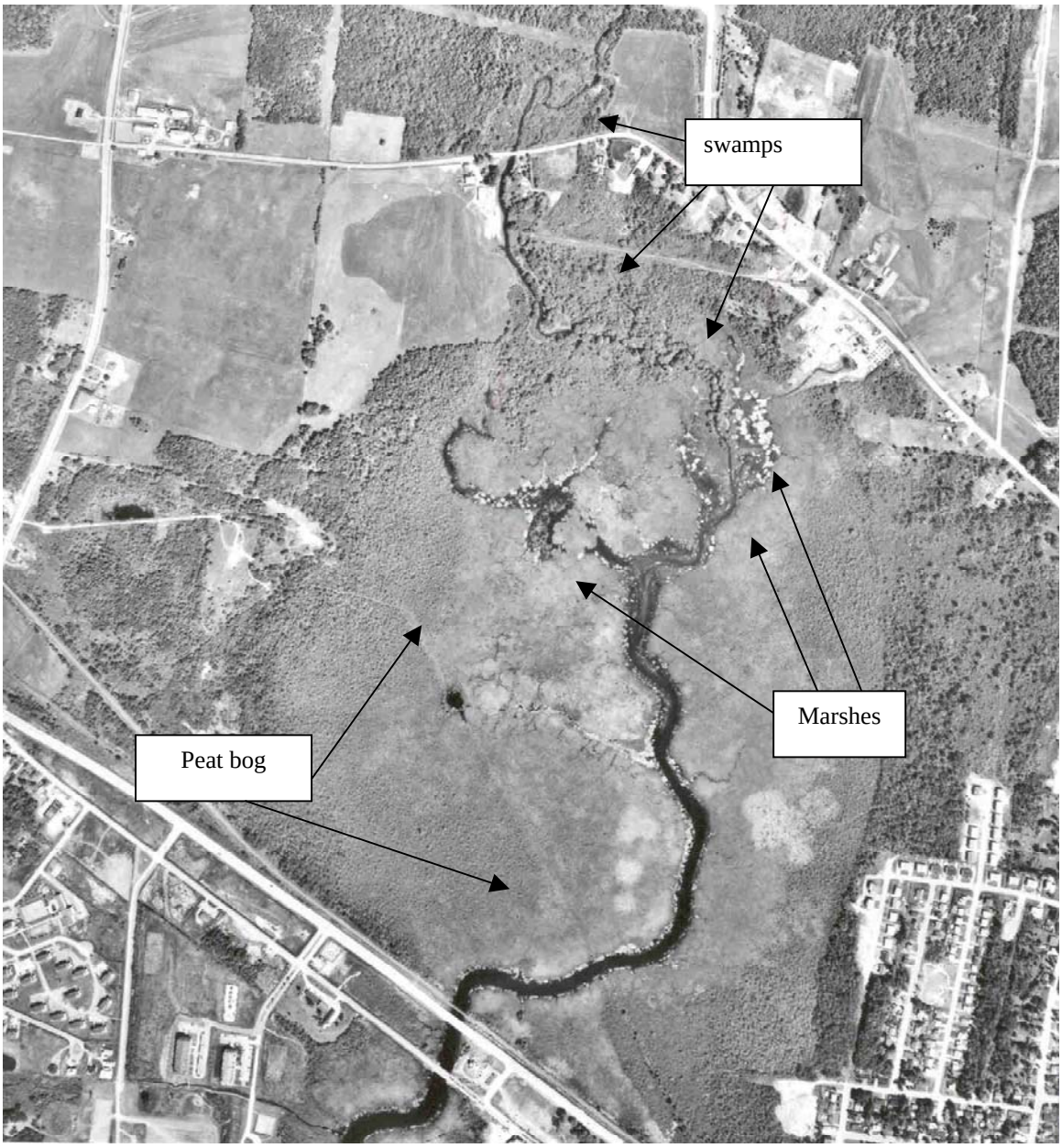


Photo HMQ98113-86, rivière aux Cerises, **Magog area (Québec)**

Figure 9 : Example of marsh and swamp areas associated to a peat bog

8- Interpretation

8.1.- Critical path

The critical path encompasses two phases: distinguishing and delimiting the form, and identifying it.

8.1.1- Distinction and delimitation

The key criterion for distinguishing **marshes** is the presence of emergent or floating vegetation at the edge of the water. However, the imagery or aerial photography must be taken at the right time during the growing season.

There are no hard and fast rules for distinguishing **swamps**, since they can easily be confused with the adjacent

forest unless water is visible between the trees. Swamps are most readily identified on the basis of their topographic position and geomorphic context. Stereoscopic interpretation is often very helpful, but delimitation from the bordering woods remains problematic.

The decisive criterion for recognizing **peat bogs** is the uniformity and flatness of their surfaces. In the case of imagery, uniform peat bogs may be confused with string bogs if the strips of water between the peat are too narrow to be captured.

8.1.2- Identification

The process of identifying marshes, swamps, and peat bogs requires that the analyst address the various elements of confusion and recognition (Tables 5 to 7). The greater the analyst's knowledge and experience, the more accurate the outcome of this labour of discrimination will be.

8.2.- Cross-checking with complementary sources of information

Inventories of wetlands and peat bogs have probably been established by branches of government in all provinces and territories, as well as by conservation groups such as Ducks Unlimited and the Canadian Wildlife Federation.

9- Elements of confusion

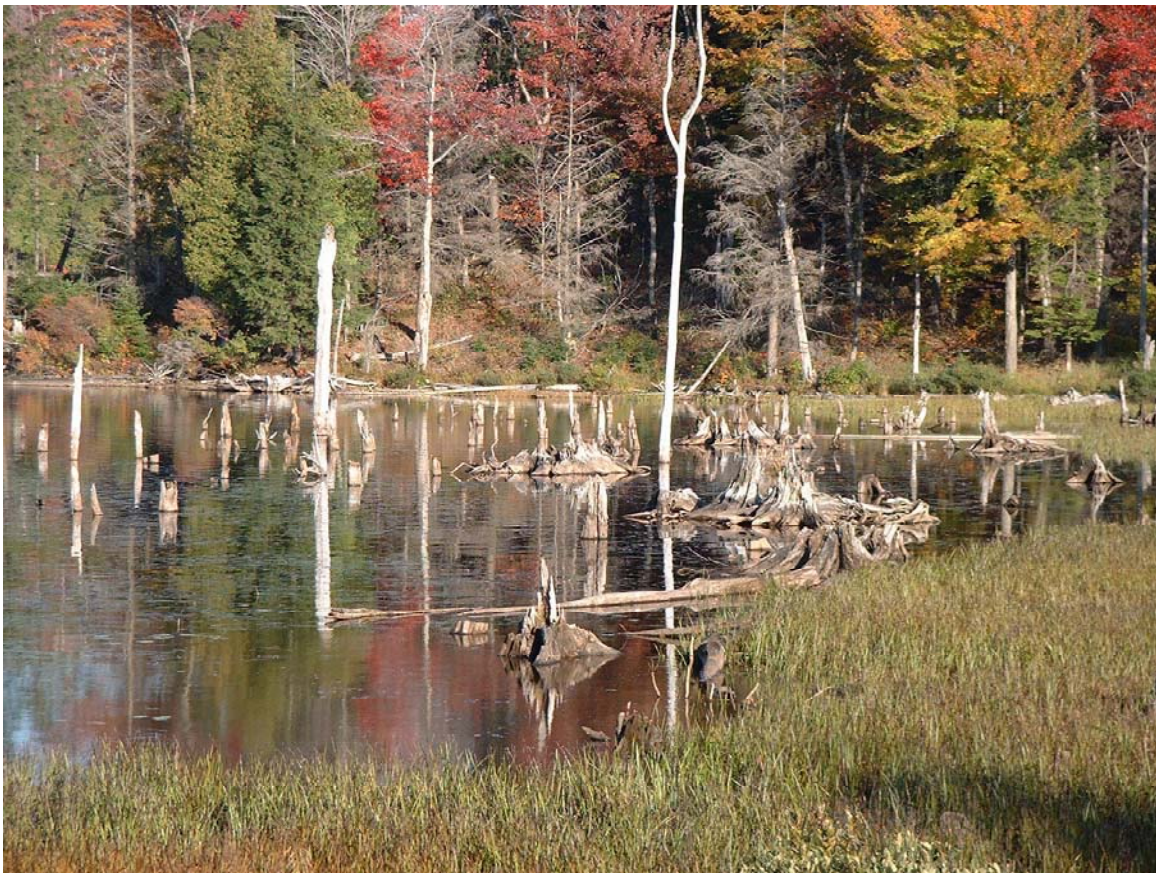
Marshes can easily be confused with sectors of shallow water, especially if the image or aerial photograph was taken prior to the emergence of vegetation. They can also be mistaken for fluvial bogs. In addition, marshes can be taken for beaver ponds with aquatic vegetation growing on their periphery. Finally, in treeless northern regions using small-scale aerial photography to distinguish between high marshes and dry land is not always straightforward.

Swamps can be confused with dry forest environments when identification relies on the appearance of the vegetation, especially on imagery.

Peat bogs are not readily confused with any other ecosystem, except salt marshes and marshes that are completely covered by dense vegetation.

Table 5: Elements of confusion and recognition between marshes and other entities or forms

Entity or form	**Elements of confusion**	**Elements of recognition**	**Examples**
Permanent water	- Absence of aquatic vegetation	- Topographic position - Date on which image or photograph taken	
Peat bog	- Plant cover - Flatness of surface	- Irregular plant cover	
Beaver pond	- Aquatic vegetation on the edge of a surface of water	- Presence of tree trunks - Small area of beaver ponds	



Source : Le Québec en images, photo 17684,

Figure 10 : Example of a beaver pond that can be mistaken with a marsh

Table 6: Elements of confusion and recognition between swamps and other entities or forms

Entity or form	**Elements of confusion**	**Elements of recognition**	**Examples**
Vegetation	- Similar plant life	- Flatness of surface - Topographic position	

Table 7: Elements of confusion and recognition between peat bogs and other entities or forms

Entity or form	**Elements of confusion**	**Elements of recognition**	**Examples**
Salt marsh	- Plant cover - Flatness of surface	- Regularity of the plant cover	
String bog	- Similar spectral signature if little water	- None - Use of aerial photography	

10- Bibliography

Buteau, P. (2001) Les tourbières du Québec : nature et répartition. Ministère des ressources naturelles du Québec, 10 p.

Buteau, P., Dignard, N. et Grondin, P. (1994) Système de classification des milieux humides du Québec. Ministère de l'Énergie, de mines et des ressources du Canada et Ministère des Ressources naturelles du Québec, Québec, 25 p.

Appendix: the meanings of the sections

1. Name of entity

The name of the entity as it appears in the GDB and in Topolan7.

2. Position in hierarchy

The position of the entity in the hierarchical structure of entities in the GDB.

3. Definition

A brief description based on the entity's principal characteristics and allowing it to be distinguished from any other natural or manmade entity in the GDB.

Only the core features are part of the definition. A detailed description of the characteristics necessary for identification is given in Section 4.

4. Summary table of elements of identification

Presentation of a table summarizing the entity's characteristics (Section 5), of the optimal conditions for identification on ETM+ imagery and black and white (B/W) aerial photography (Section 6), and of the elements of confusion (Section 9).

5. Characteristics

Categorization and description of the characteristics useful for visual identification of the entity.

5.1. Specific to the entity

Characteristics unique to the entity that allow all aspects useful for its identification to be grasped.

5.1.1. Shape

Distinction between linear, point, and areal shapes, three-dimensional pattern of the entity.

5.1.2. Dimensions

Expanse (length, width, diameter) and height of the entity: minima, maxima, and means.

5.1.3. Topographic position

Location of the entity relative to major landforms: drainage basin, mountain, plateau, plain, valley, slope, etc.

5.1.4. Drainage

Surface moisture, outside of saturated zones, in connection with the texture of the materials in the entity.

5.1.5. Vegetation

Presence of vegetation typical of the entity or patterns of plant associations making it possible to distinguish the entity.

5.2. Relative to the entity's dynamics

Characteristics pertaining to the origin and the state of the entity.

5.2.1. Emplacement process

The agent or set of agents responsible for the entity's emplacement and evolution.

5.2.2. State

Dynamic state of the entity: inherited or current. In the case of inherited features, we speak of paleolandforms; in the case of current landforms, we speak of their ongoing formation.

5.2.3. Spatio-temporal variations

Variations in the entity or its appearance that are functions of cyclical conditions (seasonal, multi-year, etc.) or event driven.

5.3. Relative to the environment

Characteristic of the conditions in the entity's milieu and its relationship with other entities or forms present in this milieu.

6. Optimal conditions for identification

Drawing on documentary sources and the experience of the participants, establishment of the optimal conditions for visual identification of the entity. Using satellite imagery, determine the capability of Landset7 ETM+ to capture the characteristics of the entity and identify the band or combination of bands best for visually distinguishing and identifying the entity. Using B/W aerial photography, identify the hues and textures that are most representative of the entity. In cases in which the relief may be significant, recommend the use of stereoscopy.

7. Examples

Illustrating the entity with examples reflecting several of its aspects:

7.3. Land-based photography

Photographs of the landscape that present one or several examples of the entity's aspects, as they might be seen from the ground.

7.3. Aerial photography

Oblique or vertical aerial photographs that present on or several examples of the entity's aspects, as they might be seen from the air.

7.3. Satellite imagery

Satellite images (from Landsat7 ETM+) that present one or several examples of the entity's aspects, as they might be seen from space.

8. Interpretation

Identification of the entity proceeds from interpreting the information in the imagery or aerial photography and complementary sources of information. The quality of the outcome of this interpretive activity will depend upon the knowledge and the experience of the analyst.

8.1. Critical path

Establishing a unique critical path of interpretation for each entity from the imagery or aerial photography on the basis of its characteristics.

8.1.1. Distinction and delimitation

The possibility of distinguishing and delimiting the shape on the image or aerial photograph has been established and the criteria for success have been described.

8.1.2. Identification

Contrasting the various elements of confusion and recognition with other entities or forms for purposes of identification.

8.2. Use of complementary sources of information

Complementing or cross-checking the interpretation with additional sources of information that are easily accessible, such as those on known Internet sites.

9. Elements of confusion

Identifying the entities and forms with which the entity in question can be confused in a table, along with the differentiating features.

10. Bibliography

A list of useful documents quoted in the previous sections.