St. Denis National Wildlife Area Land Cover Classification: 1997

J.M. Hogan and F.M. Conly

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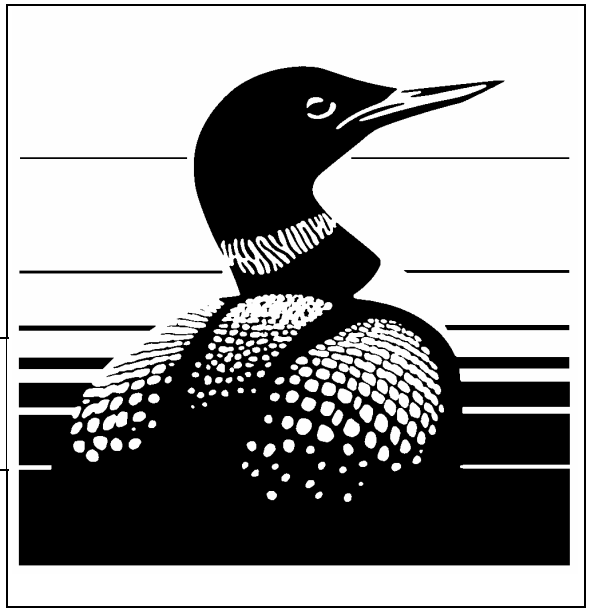

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St. Denis National Wildlife Area
Land Cover Classification: 1997

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Abstract

The land classification scheme for St. Denis National Wildlife Area (NWA) was updated using a 1: 2500 orthographically corrected photomap, which was based on aerial photography obtained October 1997. The orthophotomap was created by digitally reproducing the photos and geometrically correcting each pixel in the resulting image to remove the distortion. Geo-referencing of the image was based on four ground control points visible in the aerial photography, all of which are referenced to a UTM NAD83 projection. The land classification scheme was generated in a Geographic Information System (GIS) by identifying and digitizing seven vegetation and land use categories: ponds, wetland vegetation, trees/shrubs. native grassland, tame grassland, cultivated land and farm/rights-of-way. This report outlines the methods of map creation along with an analysis of the area of each land use category and overall accuracy of the map based on ground checking. References are made to hydrological and land use data sources for the NWA. A comparison is made to a previous land classification based on 1983 aerial photography. Identification of hydrological impacts on the wetlands from seeding cultivated land with planted grass cover at the NWA has also highlighted the necessity of documenting the spatial and temporal extent of these land use changes. This report provides a summary of significant land use changes since the site was established as well as information on recent cropping and agricultural land management practices.

Résumé

La classification des terres pour la réserve nationale de faune St. Denis a été mise à jour à l'aide d'une photo-carte au 1 : 2500 corrigée orthographiquement, basée sur une photographie aérienne obtenue en octobre 1997. La photo-carte orthographique a été créée en reproduisant numériquement les photos et en corrigeant géométriquement chaque pixel de l'image résultante pour éliminer la distorsion. Le géocodage de l'image a été réalisé en se basant sur quatre points de référence au sol, visibles sur la photographie aérienne, et référencés sur une projection UTM NAD83. La classification des terres a été générée par un système d'information géographique (SIG) en identifiant et en numérisant sept catégories de végétation et d'utilisation des terres : étangs, végétations de terres humides, arbres et buissons, prairie indigène, prairie artificielle, enclaves agricoles et terres cultivées. Ce rapport définit les méthodes de création de cartes et analyse l'étendue de chaque catégorie d'utilisation des terres ainsi que la précision globale de la carte, en se basant sur des références au sol. Des références sont faites aux sources de données hydrologiques et d'utilisation des terres pour la réserve nationale de faune. Une comparaison est effectuée avec une classification des terres basée sur une photographie aérienne de 1983. L'identification des impacts hydrographiques sur les terres humides dus à l'ensemencement de terres cultivées avec des herbes sur la réserve nationale de faune a aussi mis en relief la nécessité de documenter l'étendue spatiale et temporelle de ces changements d'utilisation des terres. Ce rapport offre un résumé des principaux changements concernant l'utilisation des terres depuis que le site a été établi ainsi que des renseignements sur les nouvelles pratiques de récoltes et de gestion des terres agricoles.

Acknowledgements

The authors wish to acknowledge Brian Yee of the GIS Section of CWS for initiating the contract to obtain the aerial photo coverage and generation of orthophoto. Minzhen Su contributed to the initial preparation of the various layers used to generate the land-cover classifications and assisted in the field. We wish to thank Steve Adams for his assistance in the field, particularly with vegetation identification and wetland classifications. David Gallén compiled the information on the agricultural land-use at the NWA. We would like to acknowledge Garth van der Kamp, Bob Clark and Philip S. Taylor for their valuable input to earlier versions of this report and to their thoughtful discussions about wetlands and wetland management. J.B. Millar was instrumental in the establishment of the St. Denis NWA and is commended for his dedication to the conscientious documentation of information, for almost thirty years at the St. Denis NWA. Dr. Millar was also very helpful during the final review of the maps provided in this report. The authors also wish to acknowledge Professor William Stolte (1943-2001) for his lifelong enthusiasm and passion in learning about the hydrology of prairie wetlands and for his keen interest in conserving this important habitat.

TABLE OF CONTENTS:

APPENDICES:

LIST OF TABLES AND FIGURES:

PHOTOS:

Introduction

St. Denis National Wildlife Area (NWA) is located at 52°12'N, 106°5'W, 4.8 km north of the hamlet of St. Denis, approximately 40 km east of Saskatoon, Saskatchewan, on highway 5 (Figure 1). The NWA was established in 1967 with the purchase of all privately owned lands on 1 ½ sections of land (361 hectares). All lands are now held by the crown. The NWA includes section 28, and the east half of section 29, township 37, range 1, west of the 3rd meridian.

Figure 1: Location of St. Denis National Wildlife Area

The NWA consists of undulating land, situated in the aspen parkland region of the Canadian prairies. Soils on this site are light textured sandy Weyburn and Biggar association loams. The NWA contains over 200 wetland areas, ranging from ephemeral shallow depressions to permanent basins. Additional background information on the NWA can be found in the St. Denis NWA management plan (Canadian Wildlife Service, 1984).

In 1985 a map was created for the St. Denis NWA (Canadian Wildlife Service, May 1983) based on 1:24,000 colour infrared aerial photography, and habitat surveys by Canadian Wildlife Service (Appendix 1). It was produced by the US

Fish & Wildlife Service using digital cartographic techniques. Map compilation and photo-interpretation were done using the APPS-IV analytical stereo-plotter. There was no written report to accompany the map. The wetland classification scheme for the 1983 map was based on vegetation zones and water level assessments completed in previous years at the NWA.

Another map of the St. Denis NWA was created in 1997 under the supervision of Brian Yee of the GIS section (geographical information system) Canadian Wildlife Service (Prairie and Northern Region) based on a 1:2500 scale orthophoto. The orthophoto was produced by SaskGeomatics from a series of 1:10,000 black and white aerial photographs obtained in October 1997. The orthophotography which was incorporated into a GIS and became the basis for a reclassification of the NWA. This report has been prepared to explain the creation of the 1997 map, land cover classifications created in GIS, and provide a summary of the land use history. A quantitative comparison between the 1983 map and the 1997 GIS map is provided, along with a listing of available aerial photography for the NWA (Appendix 2).

2. METHODS AND APPROACH TO MAP CREATION

Based on a series of 1:10,000 black and white aerial photographs for the NWA obtained in October 1997, a 1:2500 scale orthophoto was generated using a digital elevation grid with a resolution of 25m x 25m x 0.01m. SaskGeomatics employed photogrammetric methods to generate this grid from low resolution ground sample points taken from the aerial photos. An orthorectification process followed, whereby every pixel of the image was geometrically corrected. The resulting orthophoto is free of distortions and relief displacements inherent to the aerial photographs. The orthophoto was externally geo-referenced in UTM NAD83 format using four ground control points visible in the aerial photos. A higher resolution orthophoto was not attainable at the time of creation due to financial constraints

Seven major land classes and associated areas were digitized as polygons directly from the orthophoto image using Arc View 3.1©, a GIS program. Aerial photos from October 1997 were helpful in correctly categorizing the areas. Ground checking was undertaken in May and June 2001 to determine the reliability of these delineated categories.

NWA wetlands were originally mapped and numbered based on aerial photography from 1968 (J.B. Millar pers. comm.). There are 216 wetlands mapped in the NWA, with the main ones labelled from 1 to 147. Many of these larger wetlands are surrounded or adjoined by depressions which are sub-labelled with a, b, c, and d. Due to the number of depressions, they have been grouped and plotted on separate maps based, in part, on classification. Most ephemeral wetlands are represented in Appendix 3B whereas temporary, seasonal and semi-permanent wetlands are in Appendix 3A.

2.1 Classifications Based on 1997 Aerial Image

The following sub-sections describe the various land cover classifications for the NWA, as derived from the 1997 orthophoto. Maps generated with the GIS are available from scales ranging from 1:2500 to 1:500 using any combination of land cover layers. The NWA map sheet showing these classifications is in Figure 2.

Pond:

Jaime Hogan

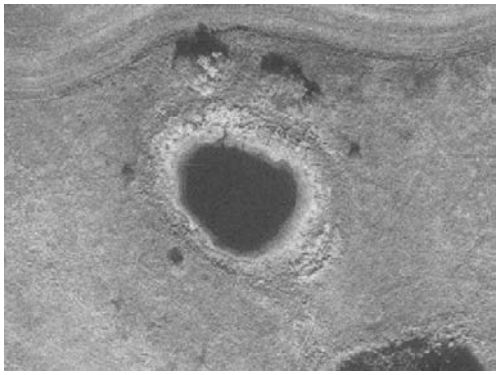
Pond classification is represented by areas of standing water, as visible on the aerial image of October 1997. This is the classification most subject to change seasonally and annually.

Photo 1. Pond 1 at St. Denis NWA looking ENE.

Wetland Vegetation:

This category represents all regions of the NWA which contain wetland vegetation, except those covered by water or invaded by trees or shrubs. Exposed mud or alkali flats associated with wetland depressions are included in this category. In accordance with Millar's (1976) classification, wetlands are defined by using the upper boundary set on the upland edge of the wet meadow. This delineation can be complicated by the transitional nature of wet meadow zones, which are significantly affected by the water regime. Occasionally willow shrubs may partially dominate wet meadow zones (Millar, 1976). Delineating wetland vegetation using an aerial source is aided by ground surveys, the uniformity of surrounding grassland reflectance, and topographic slopes.

Photo 2. (2001) The extent of marsh vegetation at pond 27 looking NW.



Pond 27 (Orthophoto, 1997)

Trees and Shrubs:

This category includes trees or shrubs identifiable on the 1997 aerial photo. Tree species consist mainly of trembling aspen (*Populus tremuloides)*, balsam poplar (*Populus balsamifera*) and willow shrubs (*Salix spp.*). Abundant shrub species includes silverberry *(Elaeagnus commutata),* snowberry *(Symphoricarpos albus)* and western rose *(Rosa acicularis).* While low shrubs often co-exist with native grasses, only areas where low shrub dominate are included in this category.

Photo 3. Mixed shrub, trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*) surrounding pond 109, looking SE.

Native Grassland:

Native grassland includes areas which have not been disturbed by cultivation, though in certain areas, it may contain non-native grasses due to invasion by tame species such as smooth brome (*Bromus inermis*).

Photo 4. Orthophoto of NWA, Scale 1:100, SW of pond 25, contrasting low shrub (top), with native grassland, tame grassland (bottom left) and cultivated land (bottom right).

Tame Grassland:

This includes any disturbed land which has been subsequently seeded with brome (*Bromus inermis*), alfalfa (*Medicago sativa*), or sweet clover (*Melilotus officinalis)* since 1977, and has since not been cultivated. Tame grassland may also include adjacent native grassland areas which are presently dominated by tame grass species.

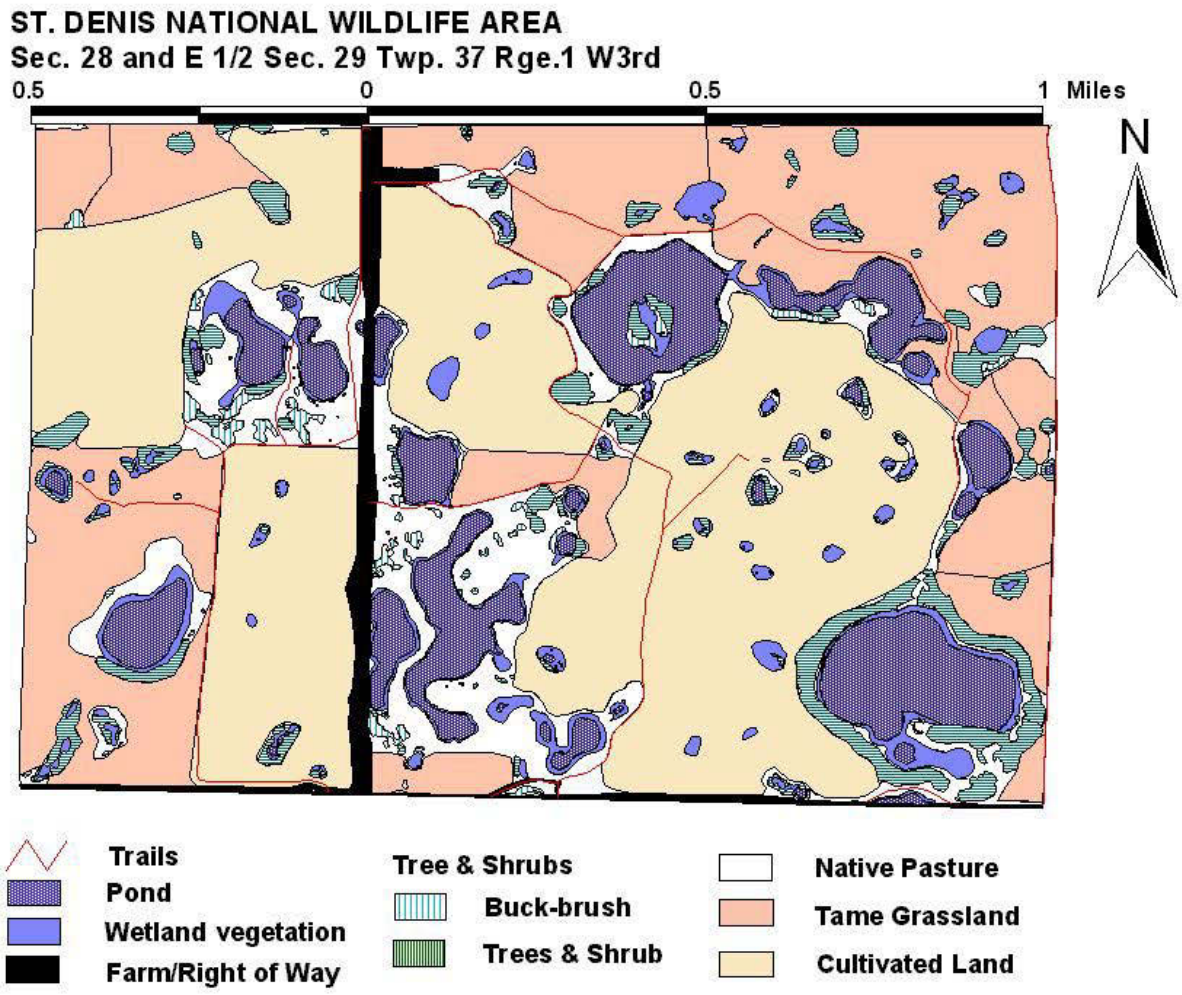
Cultivated Land:

This cover classification includes any land which was under active cultivation or fallow during the 1997 season.

Farm/Right of Way:

This classification accounts for the storage buildings in the north central part of the NWA, as well as the major grid roads, and road allowances. The storage buildings replaced a two storey farm house, which was torn down in 1990. Half of the grid road to the south is the border of the map. Commonly used trails in the NWA, although not accounted for in any individual classification, are identified on the map by linear segments.

Figure 2. 1997 Land Cover Classifications for St. Denis NWA



3. ANALYSIS OF MAP AREA

Area of the land classifications was calculated based on the sum of all the polygon areas for each class (Table 1). The total area is 392 hectares, which includes provincial crown areas – specifically Pond 90 and road allowances (Appendix 3). The extent of the wetland areas, including the wetland vegetation class, is close to 15% of the overall area of the NWA. Cultivated land still makes up the largest portion of the NWA representing 38% of the total area, followed by tame grassland with 27% and native grassland covering 11%. The trees and shrubs category on the map has been divided into the sub-categories of low shrub, and mixed trees and shrubs. In total this category makes up 6.5% of the overall area, with trees and tall shrubs making up 5.5%, and low shrubs making up 1%. Roads, right of way and farm/storage area make up the remaining 2.4%.

Table 1. Summary of Areas (Based upon areas from 1997 orthophoto)

Land Class	Total Area (hectares)	% Land Cover
1. Pond	40	10
2. Wetland Vegetation	18	4.6
3.Trees & Shrub, low shrub	26	6.5
4. Right of way & farm	9.5	2.4
5. Native Grassland	44.5	11
6. Tame Grassland	104	26
7. Cultivated	151	38
TOTAL	392	100%

4. Quantification of Map Error

4.1 Ground Checking Methods:

Ground checking verified the land classifications on the map and the positions of the boundaries separating them. Ground checking at the NWA was accomplished using a series of linear traverses from one recognisable position on the map to another, estimating how closely distances on the map matched distances on the ground. Measurements were made at fifteen different wetland sites across the NWA on at least two axes. Classifications which were more difficult to assess from the orthophoto, such as wetland vegetation and low shrub areas, were more carefully assessed on the ground. Photographs and general observations covering most of the NWA serve as further verification of the content of the various land class's.

4.2 Statistical Approach

The purpose of this statistical analysis is to determine the reliability of estimating ground distances using this map, and to evaluate the precision of the ground checking. Linear regression was used as a means of comparing digital map and field data sets. This yielded a coefficient of determination (R^2), regression coefficient (slope) of the line of best fit of the two data sets, and standard error of estimate. The coefficient of determination indicates how much variation in the map data is accounted for by the variation in the ground measurements. The regression analysis specifies the form of the relationship between the data sets by a mathematical function, $y = mx + b$. A regression coefficient (m) with a slope of one (1) indicates a perfect positive linear relationship between x and y. For this regression analysis, the y-intercept (b) was set to zero, as a measurement of zero metres on the map should also be zero on the ground. How closely this regression equation fits the data is determined by the standard error of estimate, which is a standard deviation of the differences between observed and predicted values of y.

4.3 Sources of Variation in the Map

Results of the ground checking studies (Appendix 8) show a direct comparison between measurements on the ground and measurements on the map. Percent difference is used to approximate a level of error, measurements on the ground compared to measurements on the map range from zero to 17% difference.

Understanding and quantifying errors associated with this map is important for future users. There are three main categories of error associated with spatial information: processing error, measurement/data error, and user error (Congalton, 1999).

Editing precision is limited by the pixel size and scale of the orthophoto from which vegetation and land cover layers are derived. One pixel on the digital map represents 0.3125 metres. Minimum mapping resolution describes the level of spatial aggregation of the map, or the smallest area that can be circled and identified as one thing (Berry, 1993). For this 1997 map, the minimum mapping resolution is just over one meter square, based on the mapping of individual willows and the observation screens located at ponds 1, 25, and 66. Accuracy will never be better than the minimum mapping resolution.

There is a time lapse of four years from the date of the aerial photography and the creation of the land cover map. The scale of the aerial photos is 1:10 000, and the orthophoto is 1:2500, which is sufficient to derive vegetation, land-use and cultural features. Although a GIS has great capabilities as an editing tool, there is always error associated with the creation of vegetation layers from remotely sensed data. The process involved with reducing and measuring these errors includes ground checking measurements, numerous visits to the NWA, and repeated editing in Arc View3.1©.

Changes in vegetation zonation induced by the water regime create problems in delineating the boundaries of individual wetlands (Adams, 1988). The vegetation continuum from the lowest, wettest portions of a wetland to the highest and driest, is specifically explained in Millar's (1976) report on prairie wetlands.

> "*In each wetland there is a progressive change in the composition of its vegetation… Often the continuum is a gradual one, with the overlapping of species which tolerate slightly different depths and duration of immersion. Sometimes, however, the changes in vegetation are abrupt, especially in wetlands supporting few species – or in those with steeply sloping sides*."

For this map, wetland vegetation is defined as much as possible by the presence of wet meadow zone plant communities. Natural variation in vegetation due to changing water stage is a potentially large source of error.

Field errors account for some variation in the ground measurements. Inexact starting positions for the linear traverses could be the greatest potential source of error. Elevation and directional differences will cause error of less than 0.5m for most of the traverses. The ground measurements may have been slightly overestimated due to the influence of sag on the tape measure. The mean values of the ground data set are 0.7m higher, this may be due to both wind and topographic factors. Quantification of the overall error is attempted in the following section.

4.4 Statistical Results

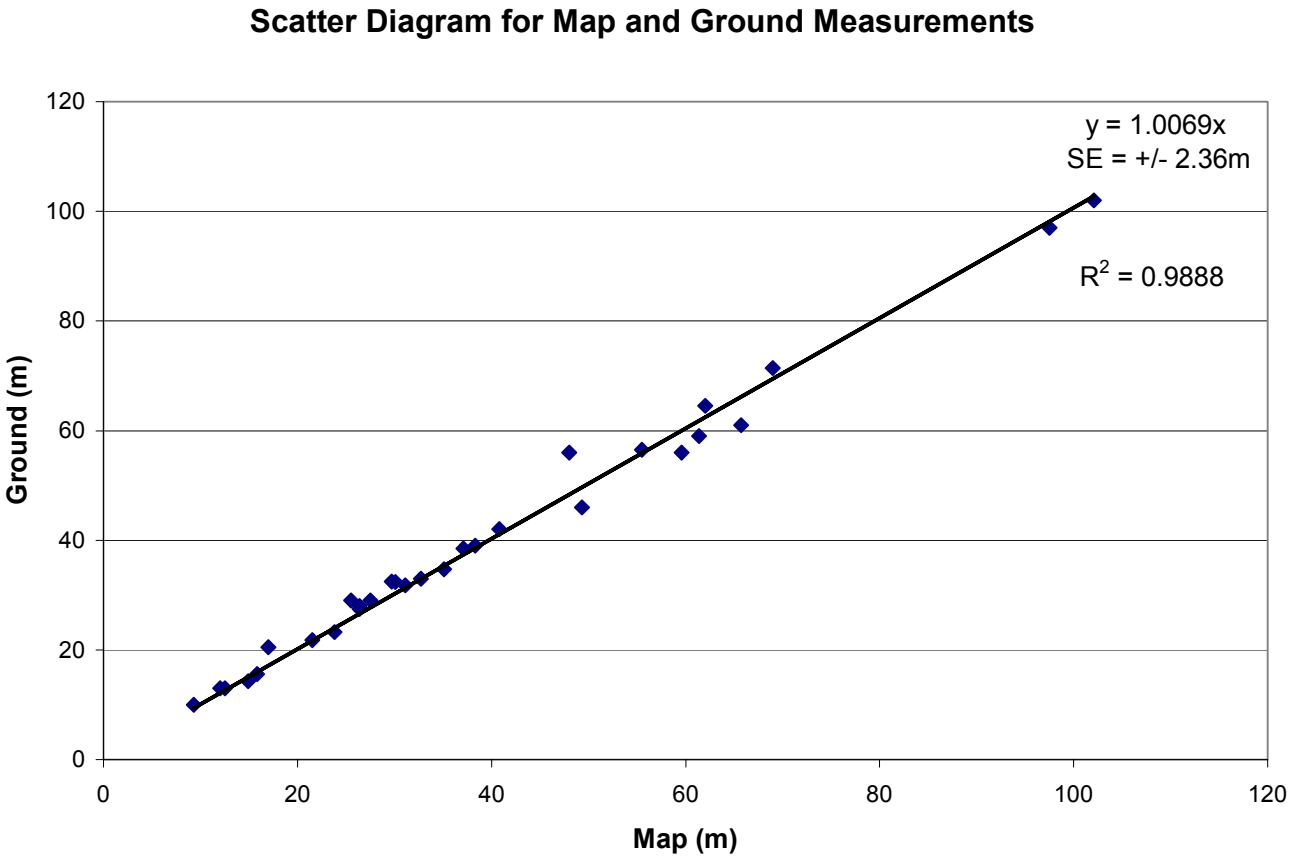
Based on the coefficient of determination (R-squared value) calculated in MS Excel, nearly 99% of the variation in one data set is accounted for by the variation in the other data set (Figure 2). Temporal changes such as the growth of the tree canopy, and the lateral spread of brush over four years may account for the remaining 1% of the total variation.

Considering that future estimates of ground distance may be made from the map, the ground data has been chosen as the dependent variable, y. Estimates of ground distance from the map can be assumed to be correct within certain limits of precision, as determined by the standard error. These limits were found to be plus or minus 2.4 m. This takes into account the possibilities of error in both data sets from various sources already mentioned.

4.5 Summary

The largest source of error on this digital map originates from the method in which the data layers such as vegetation are derived from the geo-referenced, orthorectified photographic image. The quantification of this error is based on ground checked data. Since the coefficient of determination (R^2) and the regression coefficient (slope) are nearly one, the map may be used to predict ground distances to within 2.4 m.

Figure 3. Regression analysis of the map and ground data set



5. Comparison to 1983 Land Cover Classification

This comparison is for the purpose of determining land cover trends since 1983, the last occasion when a land classification was completed (Table 2). Differences in the classification schemes between the two maps are apparent. For example, the 1983 map has separate buck-brush, woodland, right-of-way and farm yard categories. Whereas within the general trees and shrubs category in the 1997 map, buck-brush is renamed low shrubs, to allow for the mixture of species that co-dominate these areas. The road allowance and the old farm yard area are now regarded as one class. Also on the 1983 map, tame and native grass land areas were classified together. Tame grass which was planted in 1983, however, was not visible on the 1983 aerial photography and thus was classified as cultivated on the map.

5.1 Historic Land Use

The NWA was established in 1967, primarily for research on waterfowl production on agricultural lands (Canadian Wildlife Service, 1983). Nearly 60% of the 361 hectares in the NWA were under cultivation when it was established. In 1977, a program was initiated to convert parts of the tilled upland to a permanent grass and legume mix. This was to minimize erosion on sloping and light textured soils from cultivation activities, and to provide nesting cover and food for wildlife. Details of this change in land cover are contained in Appendix 4. By the end of 1983, a total of 97 hectares of St. Denis had been converted from cultivated land to grassland (Canadian Wildlife Service, 1984). Moreover, 1983 was the last year that grass was seeded on the NWA.

The agricultural land on the NWA has been continually under lease to local farmers for periods of 1 to 3 years. Unfortunately a complete historic record of crop practice does not exist for the NWA but a recent compilation of crop production is provided in Appendix 6. Farming operations have usually been carried out with care to preserve the grassland and wetland areas in their native state. Only on one occasion were these requirements dishonoured, with a variety of wetland areas burned or cultivated in the fall of 1978 (Canadian Wildlife Service, File 9275-30/S16).

Table 2. Land Cover Comparison for St. Denis NWA. Comparisons are based on a total area of 392 ha which includes the 361ha of the NWA, as well as provincial crown areas.

CLASS	1997 G.I.S. Map 1998 Area		1983 CWS/USGS Area	
	(ha)	%	(ha)	%
Pond	40	10	58	15
Wetland vegetation	18	5	-------	
Pond + wetland veg.	58	15	58	15
Cultivated	151	38	208	53
Tame grassland	104	26	100	25
Native grassland	44	11	Incl. With tame grass	
Cultivated + native + tame grassland	299	76	309	79
Trees and shrubs:	26 (total)	6.5	16 (total)	4
Trees & shrubs	22	5.5	12	3
Buck-brush	4	1	4	1
Right-of-way & farm	9.5	2.4	9.4	2.4
TOTAL AREA (ha, %)	392	100	392	100

5.2 Changes Since 1983 at St. Denis National Wildlife Area

The classification of the wetlands in 1983 was based, in part, on the wetland vegetation types and length of flooding. The central vegetation zone of the wetlands is generally used for their classification. The map contains the following categories of wetland: temporary, seasonal, semi-permanent, and intermittently exposed. These correspond to J.B Millar's (1976) numerical classification system, ranging from the driest class 1 wetlands containing mainly wet meadow vegetation, to class 5 permanent ponds or shallow open water wetlands. Intermittently exposed or open alkali ponds are rated as class 6. The ephemeral ponds characterised by low prairie zone vegetation (Stewart and Kantrud, 1971) are excluded. Examples of dominant low prairie species include: Kentucky blue grass (*Poa pratensis),* Wheat grass (*Agropyron trachycaulum),* Goldenrod (*Solidago altissima),* and Canada Anemone (*Anemone canadensis)* (Stewart and Kantrud, 1971).

Classification of the NWA from 1997 aerial imagery was initially based on the categories from the 1983 map. The primary difference is that wetland vegetation is not divided into subcategories according to vegetation zonation and water regime. The upper boundary of the individual wetlands are defined by the edge of the wet meadow vegetation. As mentioned in section 2.1, this outermost vegetation zone is transitional and often overlaps with trees and shrubs, low prairie zone species or pioneering vegetation. Due to the exclusion of trees and shrubs from the wetland vegetation category, total wetland area estimates given in section 3, may be conservative.

In September 1983, the construction to straighten the N-S grid road was completed. As shown in the map, based on aerial photography from May 1983, there were still curves in the both north-south grid road around pond 20, and the east-west grid road near pond 79. These construction activities disturbed pond 20 and eliminated small wetlands 21 and 22, which were located on the right of way, south of pond 20. Construction to straighten the E-W grid along the southern boundary of the NWA near Pond 79 was completed after 1988.

The total area of tame grassland, estimated from the 1997 aerial image has increased from 97 to 104 hectares, yet no additional seeding has occurred since 1983. Clearly the smooth brome (*Bromus inermis*) has been very competitive and has successfully invaded regions once dominated by other native grasses. Disturbance of native grass areas within the NWA by cultivation and burning would have likely hastened this process. In July, 2001, certain tame grassland areas of the NWA were hayed for the first time since they were established (Appendix 5). These haying activities were designed to determine the impact on wetland inundation regimes.

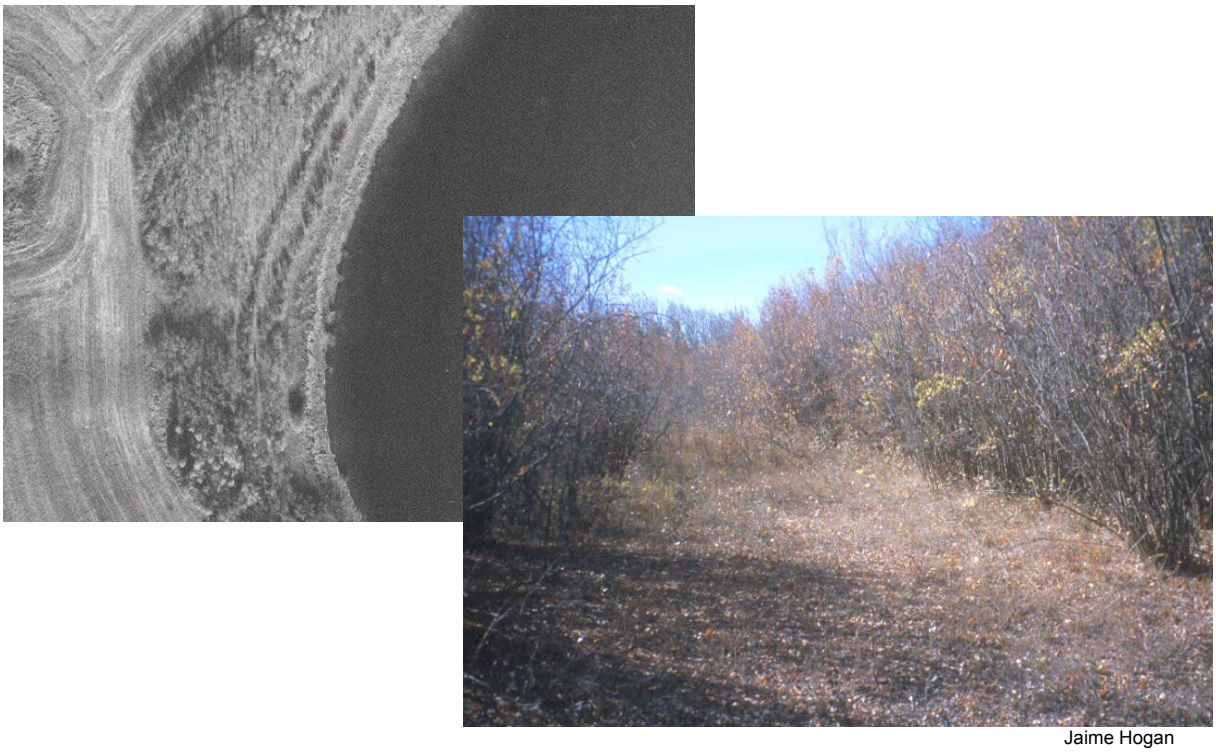
The introduction of permanent cover around some wetlands has affected their hydrologic regime. Specifically, some wetlands dried out a few years after this conversion whereas wetlands in the neighbouring cultivated area maintained their hydrologic characteristics (van der Kamp et al., 1999). In many circumstances this effect was delayed by a few years as is evident on the hydrograph for pond 92 (top Appendix 7). Pond 92, for example, held water temporarily from 1968 to 1986, thereafter it was

dry on the surface. Unlike the other wetlands in Appendix 6, pond 92's drainage basin is situated entirely in tame grassland. van der Kamp et al. (1999) speculated that brome grass is a particularly effective snow trap, reducing the amount of snow that is transported by wind from the uplands into the wetlands. In addition, increased infiltration in the uplands would limit the amount of runoff. Interestingly, these wetlands have not re-flooded, even in years of high precipitation. As a result of these changes, the continuum of wetland vegetation in these ponds has shifted in favour of low prairie or upland vegetation, and allowed for the expansion of woody vegetation.

In spite of the impact on some wetlands as a result of the introduction of permanent grass cover, the total area of wetlands between 1983 and 1997 has changed little. For the 1997 map, wetland habitat represents 14.7% of the total area of the NWA. Wetland habitat is based entirely on the combined area of standing water and the wetland vegetation surrounding it, excluding trees and shrubs. For the 1983 map, the wetlands are subdivided into temporary, seasonal, semi-permanent and intermittently exposed alkali categories, making up 14.8% of the NWA. These classifications were based both on the dominant vegetation zone occurring in the central or deeper part of the wetlands, and the stability of the water levels (Stewart-Kantrud, 1971). Despite different methods of delineating wetland habitat coverage, the two map sources indicate that the total area of the wetlands at the NWA has not changed in 14 years. This is not unreasonable considering that the hydrologic regime at the time of the aerial photography in both 1983 and 1997 was very similar, as depicted in historic hydrographs (Appendix 7).

Trees and shrubs on the NWA are mainly located on the borders of depressions, and in the adjacent upland areas not subject to cultivation. Since 1978, there have been no burns or cultivation in slough areas. The extent of trees and shrubs has increased by 50% (9.4 ha) in 14 years. This increase has largely been at the expense of the surrounding uplands predominantly the tame and native grasslands. Recent evidence from ground checking, however, indicates that aspen (*Populus tremuloides, P. balsamifera*) and willow (*Salix sp*.) are encroaching towards the centre of some wetlands. Wetlands which dried out after the surrounding uplands were converted to permanent grass cover are particularly susceptible (van der Kamp et al., 1999). The impact of this succession of woody vegetation into the centre of these wetlands over the long term is uncertain. Although most of these ponds seem to follow a general pattern of seral succession, there are some that display a discontinuity. For example, on the NW shoreline of pond 90, there exists two prominent willow rings about 3m high and several metres apart (Photo 6). The reasons for this discontinuity in woody vegetation communities are unclear but are likely linked to the flooding regime of individual pond.

Photo 5. Willow Rings on the NW shore of pond 90. (St. Denis NWA orthophoto, 1997 and photograph, 2001)



Jaime Hogan

5.3 Conclusion

The area of the wetlands at the NWA seems to be unchanged between 1983 and 1997, although there are some differences in the wetland classification approaches used between the two periods. Wetlands which have been impacted by the introduction of permanent grass cover and that no longer hold water in spring are undergoing a shift from marsh dominated species to upland and low prairie vegetation. Since 1983, brome grass (*Bromus inermis*) has invaded adjacent native grassland and wetland areas, and tree and shrub stands have grown up in many previously open wetland depressions. The total area of trees and shrubs has increased by 50% (9.4 ha). If dry climatic conditions persist, it is expected that additional inward migration of trees and shrubs towards the centre of the wetlands will occur, especially for those surrounded by tame grassland.

6. REFERENCES

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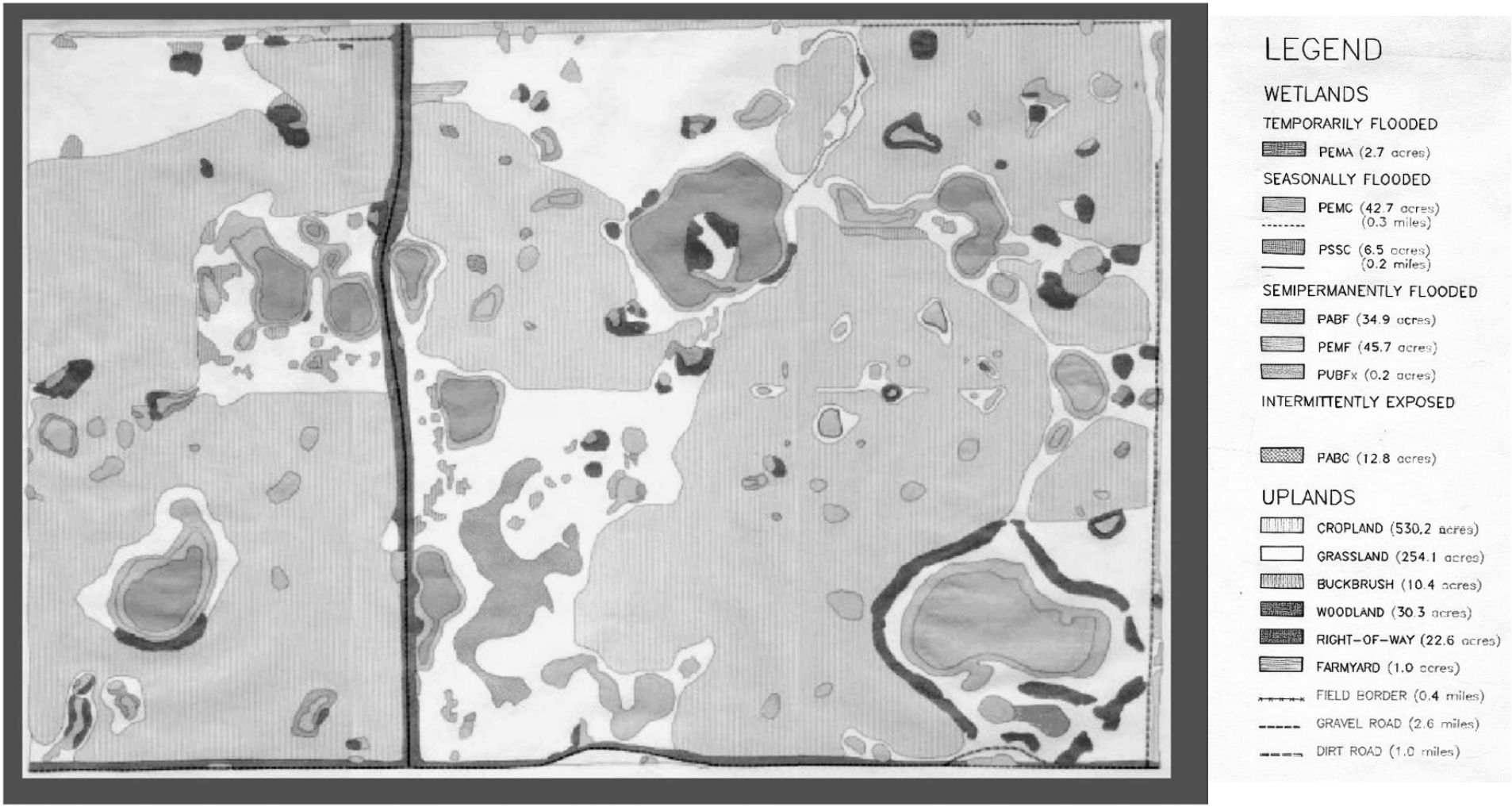
Appendix 1. 1983 Map of St. Denis National Wildlife Area. This is a scanned and reduced version of 1:4800 hardcopy map.

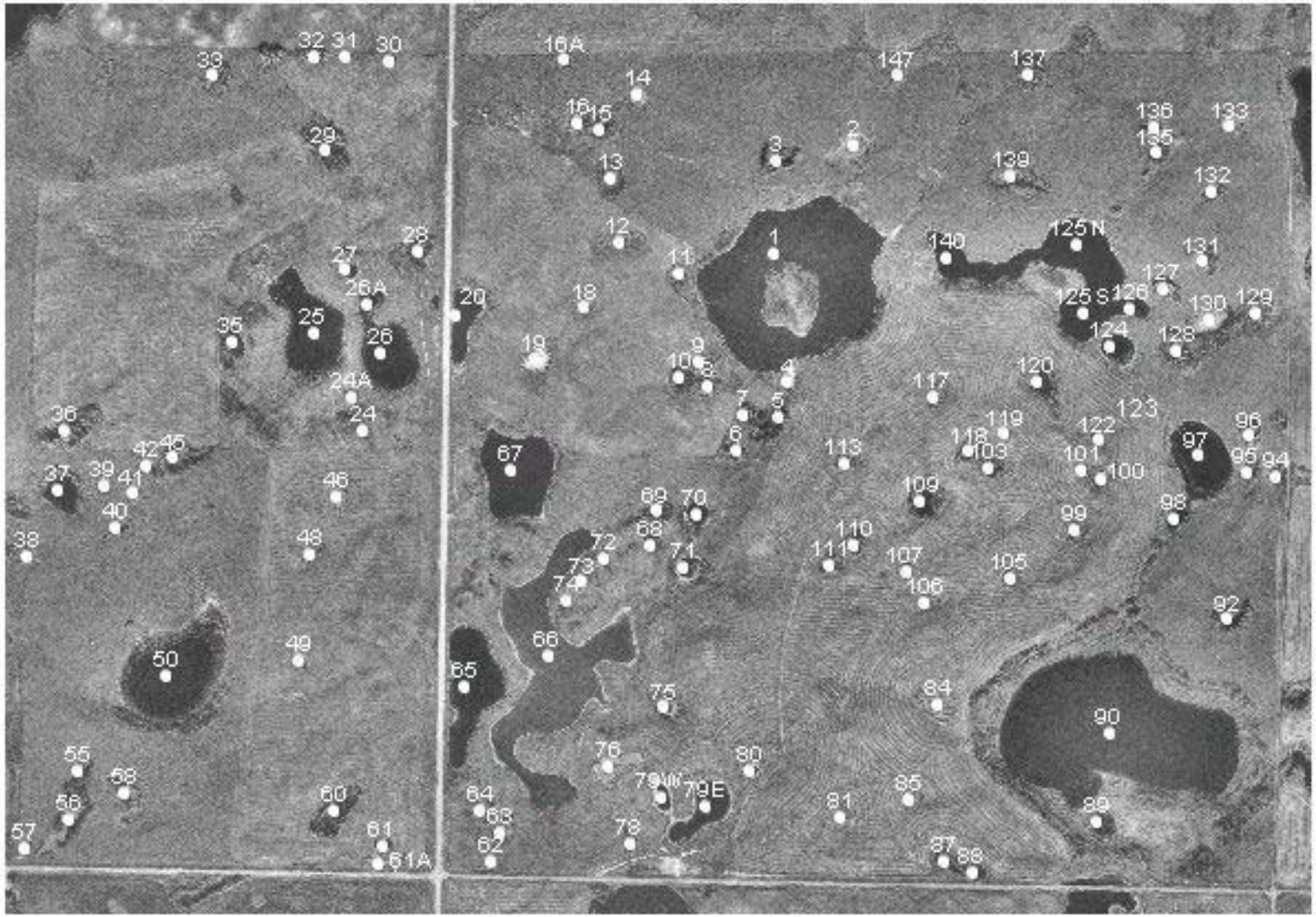


Appendix 2. Historical Aerial Photography for St. Denis NWA

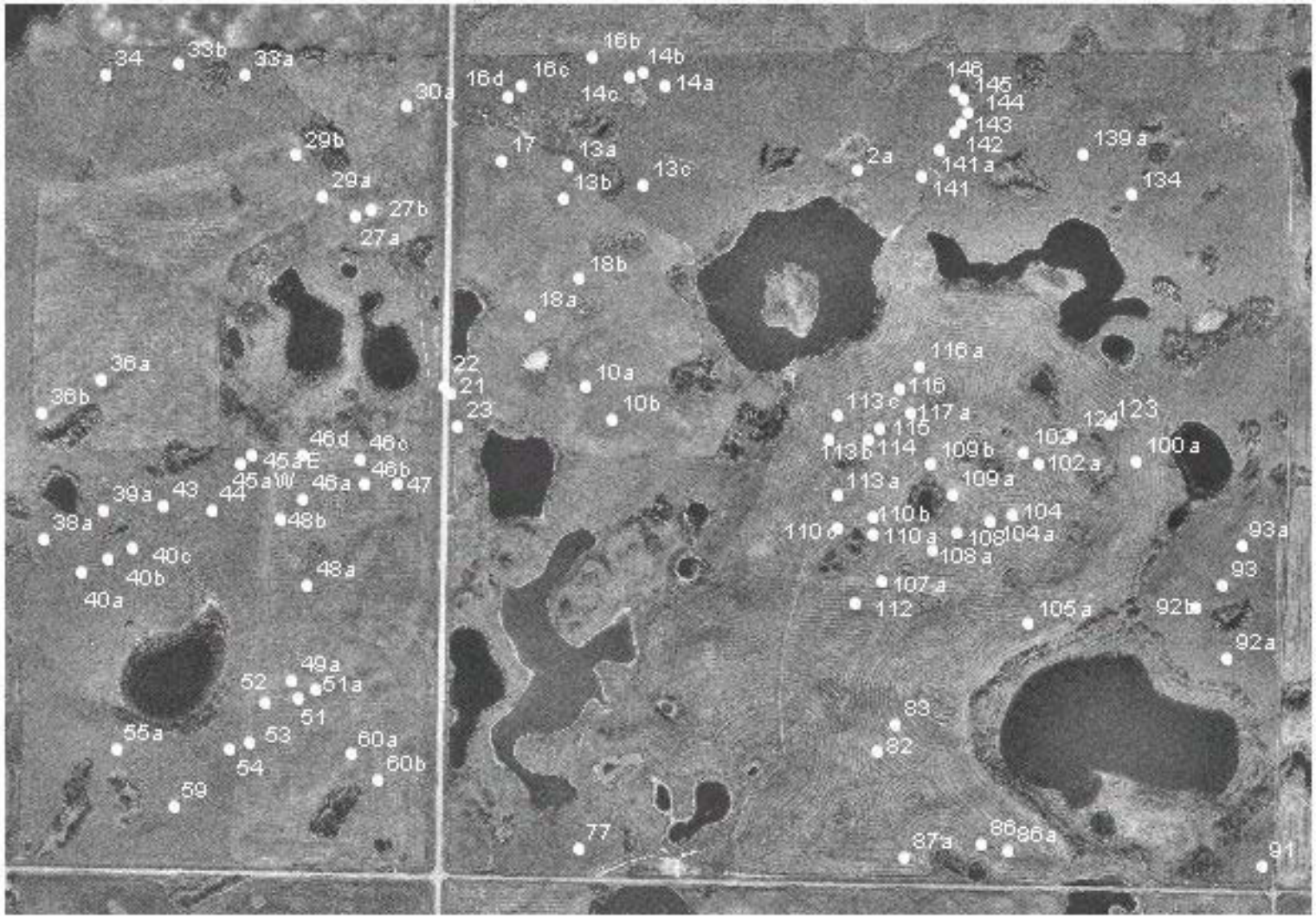
DATE	SCALE *	AP NUMBERS	OTHER INFO.
17/10/1997	1:10 000	97710-02-107en114	Black and white
26/05/1983	1:24 000	N/a	Slide & hard copy
07/1983	1:24 000	N/a	Colour slide & hard copy
05/1980	1:12 700	5-283 en 284	B&W
05/1980	1:12 000	5-272 en 276	B&W
18/06/1976	1:8200	216 en 221	B&W
28/05/1974	1:6000	40,42,44, 2 unlabelled proofs	B&W
05/1973	1:6000	A310 en A313	B&W
1970/1972	1:6300	Unlabelled	Small size
05/1970	1:15 800	A 21481-52 en 55	B&W
08/1968	1:15 800	A 20677-24 en 25	B&W
08/1968	1:15 800	A 20677-36 en 37	Partial coverage of NWA
08/1968	1:8000	A 20676-4 en 7	Partial coverage of NWA
08/1968	1:8000	A 20676-13 en 16	Map and AP report incl.
05/1968	1:15 800	A 20428-45 en 46	Partial coverage of NWA
05/1968	1:15 800	A 20428-54 & 56	Map included
1962	1:28 000	A 17792-94 en 97	B&W
1962	1:16 000	A 17792-38 en 40	B&W
1962	1:15 800	A 17792-82 en 84	B&W
1962	1:8200	A 17792-113 en 116	B&W
1962	1:8200	A 17792-141 en 142	Partial coverage of NWA
1959	1:15 800	A 16632-108	S. bend on N-S grid straightened
1950	1:16 000	A 13344-188 & 190	B&W
1950	1:16 000	A 13344-140 en142	Map included
Prior to 1959	1:36 000	A 15450-95,128,130	RCAF, spring
After 1959	1: 15 800	A 21481-54 (pair)	Energy, Mines &Resources

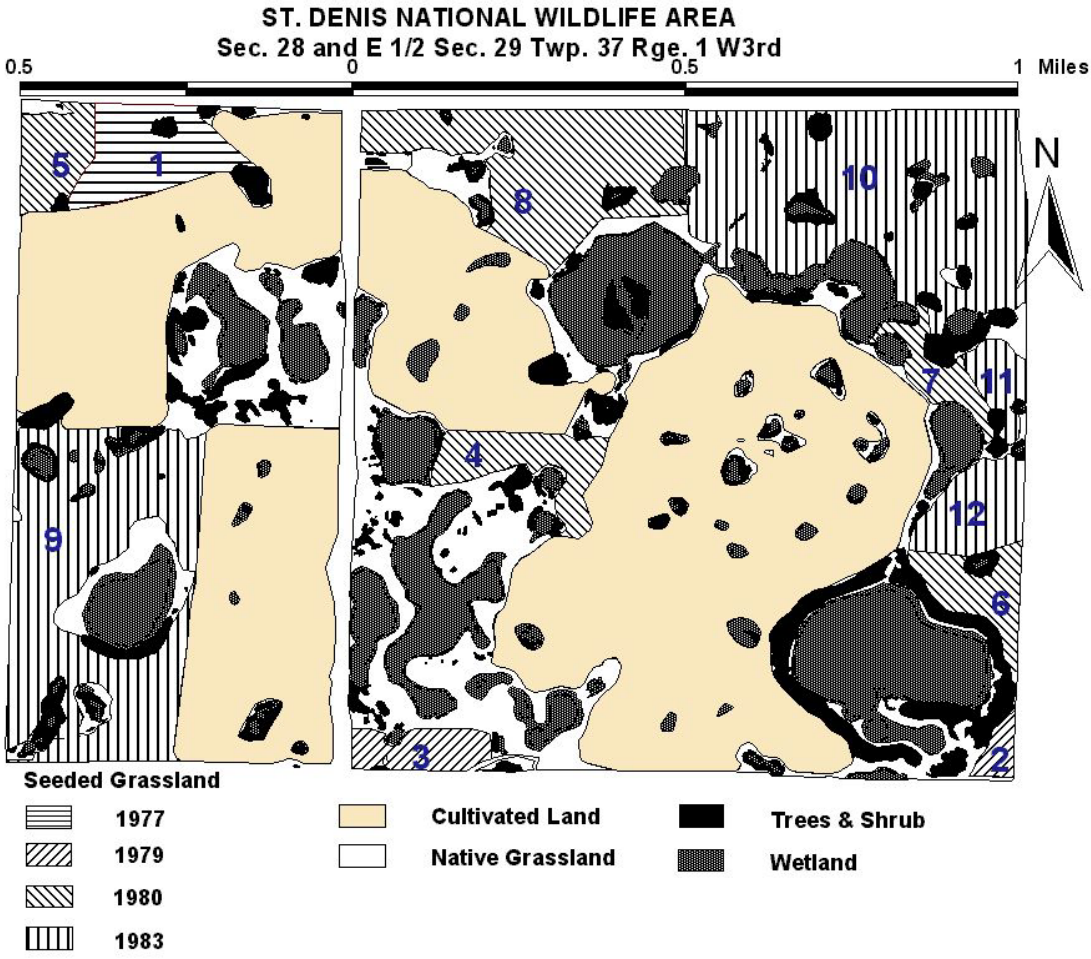
- Scale based on number of inches on photo representing one mile on ground.

Appendix 3A. Numbering for seasonal, semi-permanent, and permanent wetlands. (J.B.Millar. Pers. Comm) (St. Denis NWA Orthophoto, 1997)



Appendix 3B. Numbering for ephemeral and temporary wetlands



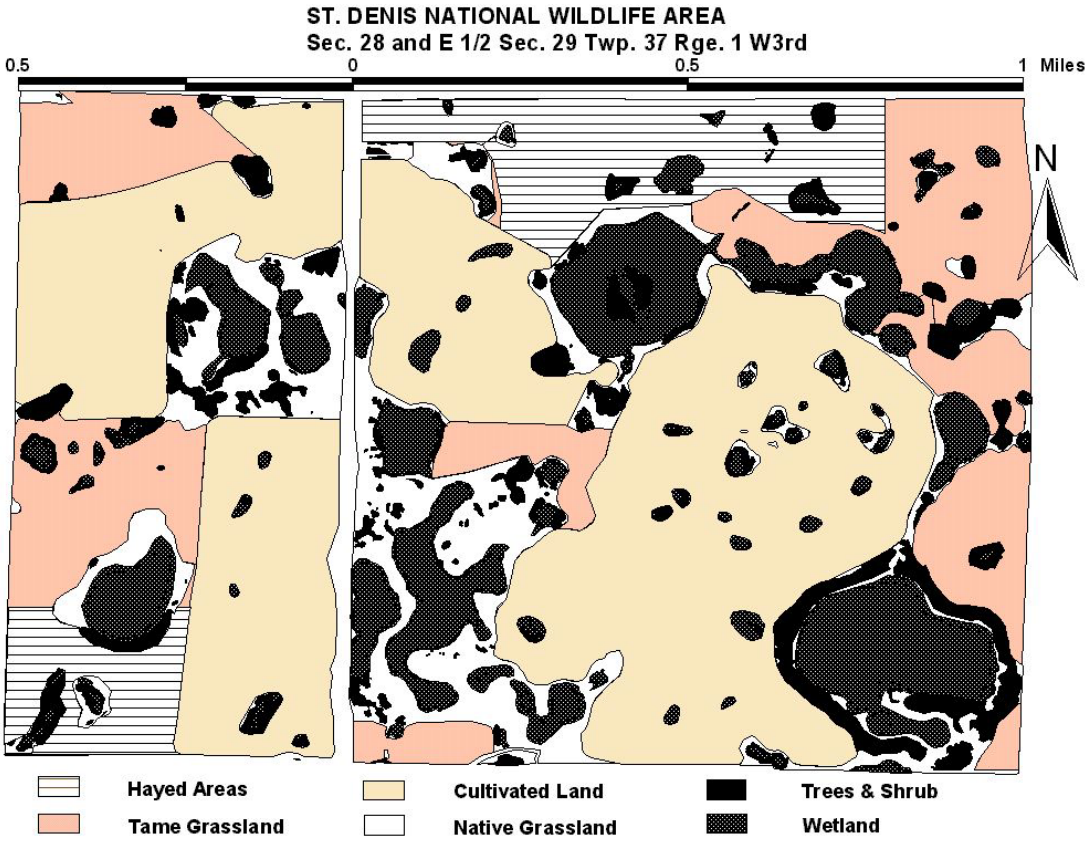


Appendix 4. Area of Tame Grassland at St. Denis NWA and Year Seeded

Area of Tame Grassland Parcels (hectares):

Parcel #	1	2	3	4	5	6	7	8	9	10	11	12
Year	77	79	79	80	80	80	80	80	83	83	83	83
Area	6.51	1.16	3.00	5.00	3.96	3.75	2.55	16.19	25.07	30.38	2.16	4.88
Total Area/ Year	6.51		4.16					32.72				62.14

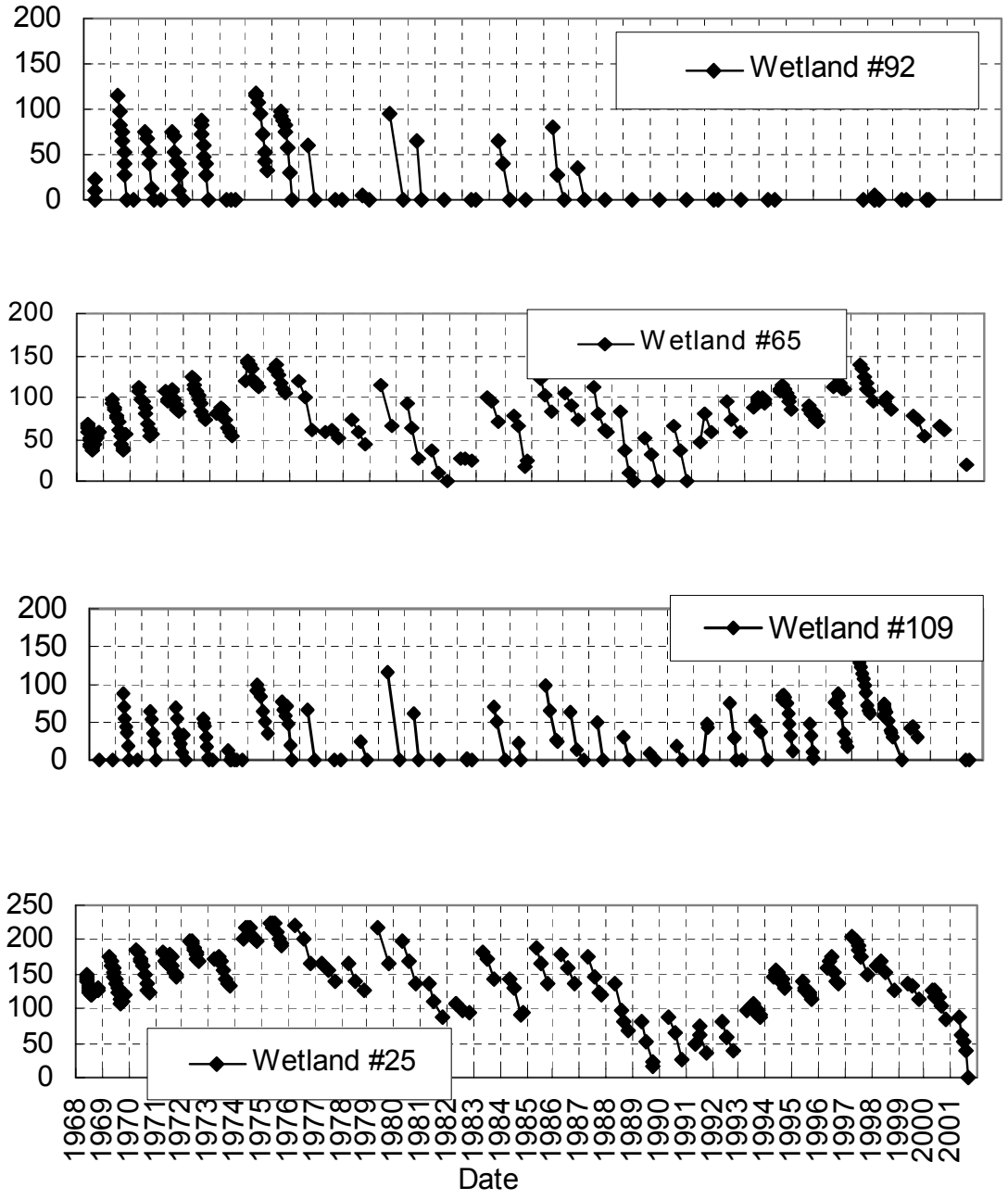
Appendix 5. Areas of the NWA Hayed in July 2001



Appendix 6. Crop Information. This information was obtained by David Gallén in personal communication with Mark Denis, farm contractor.

Quarter Section:	Year(s):	Crop:	Other divisions/comments:
Section 29 NE ¼	2001	Canary seed	78 acre plot
	1998- 2000	Wheat	
	1997- 1999	Canola	
Section 29 SE ¼	1997, 2001	Canola	70 acre plot across from pond 50
	1990,96,2000	Fallow	
	1999	Lentils	
	1995,1998	Wheat	
	1997	Canola	
Section 28 NW ¼	1996, 99,2001	Canola	58 acre plot near farm/shed site
	1995, 2000	Fallow	
	1997	Wheat	
Section 28 NE ¼	2001	Flax	85 acres above quarter section line
	2000	Wheat, peas	Top 64 acres wheat, ~20 acres peas
	1999	Peas	
	1998	Fallow	
	1995	Cereal crop	
Section 28 SE ¼	2001	Flax	Bordered by trail to the West
	2000	Peas, Lentils	Top 21 acres peas, lower 85 lentils
	1993-4, 97, 99	Wheat	
	1996	Canola	
	1995	Fallow	
	1986	Wheat	
Section 28 SW ¼	2001	Flax	70 acres West of trail
	2000	Wheat	
	1996,1999	Canola	
	1998	Chem Fallow	
	1997	Cereal crop	

Appendix 7. Hydrographs for several St. Denis Ponds from 1968 to 2001 (cm) (Updated wetland water level data from Conly and van der Kamp, 1999)



Appendix 8. Table of Ground Checking Data

Map: **Ground:**

Pond #	Axis 1 N-S *	Axis 2 E-W	Axis 1 N-S *	Axis 2 E-W	Comments:	Percent Difference **
37	62.0 m	69.0 m	64.5 m	71.4 m	Measured from inside of trees	3.7 %, 3.3%
39	30.1	23.8	32.4	23.3	Edges defined by gauges	6.9%, 2.3%
70	40.8	37.1	42	38.5	Water edge (Map) inside edge of reeds (Ground)	2.8%, 3.5%
80	26.4	12.5	28	13	Measured water's length, width	5.7%, 4.2%
80	25.5	27.5	29	29	Measured diagonal, and length from water to crop edge	12%, 5.2%
110	31.1	26.4	31.8	27.5	West edge of trees, North axis from outer edges *	2.2%, 4.0%
Shed	21.5		21.8		SE corner of shed to crop edge	1.3%
50	9.3		10m		Distance between trees on east side, over the path	7.0%
1	14.9	15.8	14.3m	15.6m	Road to edge brome, estimated edge of basin #1	4.0%, 1.2%
125	12.0	17.0	13m	20.5	Road to edge brome, edge pond Water levels higher in 1997	7.6%, 17%
139	29.7	102.1	32.5	102m	Inside treed wetland	8.6%, 0%
124	38.3		39m		Inside willow ring to trees of #28 (not N-S)	1.8%
130	61.4	65.7	59	61	From west edge of trees east, perpendicular transect	3.9%, 7.1%
109	59.6	32.7	56	33	NW-SE, NE-SW(240deg)	6.0%, 1.8%
117	49.3	35.1	46	34.7	From middle of trees N-S, edges E-W	6.7%, 1.1%
89	97.5		97		N-S transect bordering 89, between large aspen groves	0.5%
89	55.5	48	56.5	56	Length, width of hardstem reeds on ground, water	1.8%, 14%

* **NOTE:** N-S axis traverse is compass bearing 13°E of Grid North.

** Difference $=[(X_1 - X_2)\ X_1] * 100$ where $X_1 > X_2$

Over 50% recycled

paper including 10%

post-consumer fibre.