Ecosystem Service Approach Pilot on Wetlands:

Assessment of Current and Historic Wetland Carbon Stores in the Sheppard Slough Area

A Report Prepared for Alberta Environment and Sustainable Resource Development for the Ecosystem Services Pilot Project by Ducks Unlimited Canada

FINAL REPORT

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TABLE OF CONTENTS

Introduction: 2

Wetlands and Carbon 2

Ecosystem Services Approach Pilot on Wetlands 2

Methods: 4

Historic (1962) and Current (2005) Wetland Inventories 4

Historic data: 4

Current data: 5

Other DUC Wetland Inventory Data: 5

Assessment of Wetland Carbon Stores and changes in Wetland Carbon Stores between 1962 and 2005 6

Results and Discussion: 8

Historic (1962) and Current (2005) Wetland Inventories 8

Assessment of Wetland Carbon Stores and change in Wetland Carbon Stores between 1962 and 2005 8

References: 9

Introduction:

Wetlands and Carbon

Although only 1 per cent of the Earth's surface is covered by inland waters such as ponds, lakes, rivers, streams, and wetlands, these systems play a significant role in the global carbon cycle compared to terrestrial and marine systems (Battin et al. 2009). Wetlands, which are the interface of aquatic and terrestrial environments, are particularly important in the global carbon cycle. While peatlands are responsible for most of the carbon stored in wetlands soils, freshwater mineral soil wetlands also store globally significant amounts of carbon. In North America, freshwater mineral soil wetlands account for 18 per cent or approximately 40Gt of the wetland carbon pool (Bridgham et al. 2006), equivalent to 5-6 times the average annual amount of C emitted through the burning of fossil fuels globally.

The North American Prairie Pothole Region (PPR) is approximately 800,000 km^2 and extends from north-western Iowa in the United States to into central Alberta Canada. This landscape is covered with millions of freshwater mineral soil wetlands, typically referred to as prairie potholes. However, this vast area of hydric soils has been significantly altered due to agricultural conversion and drainage which has resulted in approximately 70per cent of wetlands being lost: (http://atlas.nrcan.gc.ca/site/english/learningresources/theme_modules/wetlands/index.html) in the Canadian prairies.

The alteration and drainage of wetlands greatly decreases the amount of soil organic carbon contained within these systems by accelerating the oxidation of stored carbon and its release to the atmosphere as carbon dioxide (Armentano and Menges, 1986). Studies conducted in the Canadian Prairies indicate that wetland drainage is accompanied by approximately a 90 Mg ha^{-1} decrease in SOC (Badiou et al, 2011; and Bedard-Haughn et al., 2006).

Ecosystem Services Approach Pilot on Wetlands

The Ecosystem Services pilot is part of the longer term Ecosystem Services Roadmap intended as a tool under the Cumulative Effects Management Framework to help inform trade-off decisions and assure more robust decision-making. The Ecosystem Services pilot team was mandated to demonstrate the use and replicability of the ecosystem services to support Alberta Environment and Sustainable Recourse Development priorities. Using an ecosystem services (ES) approach is an opportunity for decision-makers to recognize previously unseen benefits as well as mitigate some unforeseen impacts stemming from development choices. By examining the environment through a framework of ecosystem services, decision-makers will have a more complete picture of

the social, economic and environmental consequences, values and perspectives of development, and conservation activities on the landscape. The Sheppard Slough Drainage Catchment situated to the east of Calgary was chosen as the case study area boundary.
This report focuses on assessing the carbon storage associated with class 3 (seasonal), class 4 (semi-permanent), and class 5 (permanent) wetlands in the Sheppard Slough Drainage Catchment.

The specific goals of this assessment were to:

1. Determine the stock of carbon contained in existing wetlands within the Sheppard Slough Study Area, and to;
2. Estimate the amount of carbon dioxide re-emitted to the atmosphere as a result of wetland loss between 1962 and 2005 in the Sheppard Slough Study Area.

Methods:

Historic (1962) and Current (2005) Wetland Inventories

Historic and current wetland inventories for the Sheppard Slough Study Area were based on data collected from a change detection analysis conducted for the Rocky View County municipal district. This change detection analysis was carried out by Ducks Unlimited Canada (DUC) with funding from the Government of Alberta. The operational motivation for initiating change detection projects in the Prairies has been primarily driven by DUC's requirement to identify physical wetland restoration opportunities across large tracts of geography. The method attempts to identify changes to wetland area between a 'pre-development' (T1) historical benchmark and the current condition (T2). The method extends beyond a simple T1-T2 approach in an attempt to isolate transitory loss (i.e. cultivation, natural variability) from losses incurred by hydrologic alteration and to estimate wetland restoration potential of each wetland by assuming the historical extent of hydrophytic vegetation.

Protocols and procedures have been developed to photogrammetrically collect wetlands and agricultural drainage features in a soft-copy environment for both current and historical aerial photography. The method employs a small minimum mapping unit of 0.02 ha in order to build a representative inventory for both epochs which adequately captures the range of wetland sizes that are common in the Prairie environment. Wetlands features are defined by incorporation of both vegetation and topographic indicators, furthermore stereo is also critical for distinguishing anthropogenic drainage from natural topographic breaks that occur across the landscape. Given the large labor requirement associated with the manual collection of often thousands of wetlands, the ecological depth of the classification has been reduced in order to control project cost. For high resolution change detection projects the classification of the wetland is restricted to collecting the wetland emergent communities, the open water portion of the wetland, and cultivated portions of the basin. No attempt is made to assign permanence classes to the basin or to separate the vegetative communities within the wetland margin.

Historic data:

Overview: Historic Wetland Inventory was derived from stereo photography flown in June 1962. The following wetland classes were collected: Wetland (Emergent Vegetation) - Hydrophytic vegetation occupying wetland basin, Wetland (Open Water) - Open Water within an intact wetland basin or Open water zone in dry basin. Wetland (cropped basin) - Cultivated depression or wetland margin defined by topography and the presence of water or recent evidence of flooding, this includes depressional areas altered by agricultural activities.

Details: Wetland data was stereo collected from BW 1962 1:30,000 frames flown in June 1962 (AS830) and scanned from the original rolls housed at Alberta Environment and Sustainable Resource Development (ESRD).

Current data:

Overview: Current Wetland Inventory derived from photography flown in the 2005 growing season. The following wetland classes were collected: Wetland (Emergent Vegetation) - Hydrophytic vegetation occupying wetland basin, Wetland (Open Water) - Open Water within an intact wetland basin or Open water zone in dry basin. Wetland (cropped basin) - cultivated depression or wetland margin defined by topography and the presence of water or recent evidence of flooding, includes depressional areas altered by agricultural activities.

Details: Wetland data was photogrammetrically collected from existing true color 1:30,000 frames acquired in 2005 to compile the MD of Rockyview municipal orthophoto mosaic. The imagery was not flown on one single date and represents a number of days throughout the 2005 growing season.

Other DUC Wetland Inventory Data:

In order to assess the carbon stores associated with wetlands in the Sheppard Slough Area it is necessary to know what portion of the basins are class 3 (seasonal), 4 (semi-permanent), and 5 (permanent). As mentioned in the previous section, DUCs high resolution inventories and change detection analyses do not assign permanence classes (see Stewart and Kantrud, 1971) to wetland basins as the number of wetland basins involved at the geographic scale involved in these studies would be unmanageable. For this reason we have chosen to draw upon other DUC research sites within a 150 km radius of the Sheppard Slough Study Area where we have detailed wetland inventories that include Stewart and Kantrud permanence classification (Figure 1). How this information was used to assess wetland carbon stores in the Sheppard Slough Study Area is described in the following section.

This supplemental wetland inventory data was derived from three large studies conducted by DUCs Institute for Wetland and Waterfowl Research:

1. Prairie Habitat Joint Venture (PHJV) Assessment Study (1993-2000)
2. Pintail Duckling Survival Study (2005-2007)
3. Spatial and Temporal Variation in Nest Success of Prairie Ducks (SpATS, 2002-2011)

Wetland classification information at these study sites was collected using manual photo interpretation along with ground-truth methods. Aerial photography taken at “peak of

green" during July was used for initial digitizing, and if necessary was supplemented with current SPOT imagery (2.5 m panchromatic) to update habitat and land-use changes. The PHJV Assessment study used aerial photographs at a scale of 1:5,000, the Pintail and SpATS studies used aerial photographs at a scale of 1:10,000.

Assessment of Wetland Carbon Stores and changes in Wetland Carbon Stores between 1962 and 2005

The drained basin impact model created for the Alberta Government's *Water for Life* strategy attempts to characterize the current status of a depression by determining if a basin has been drained or impacted between historic and current epochs. For basins that no longer sustain emergent communities the historical wetland extent is used to estimate the potential area that could be recovered if hydrology was restored or if cultivation disturbances were to cease. As such, the model does not explicitly report area losses/gains of wetlands that still have remnant emergent communities. Given this deficiency (and for practical purposes) the comparison across epochs was confined to areas mapped as emergent and open water. Note: cropped wetlands were excluded from this analysis in both epochs.

Wetland carbon stores were estimated for class 3, 4, and 5 wetlands in the Sheppard Slough Study Area based on previous research conducted by DUC on wetlands in the Canadian prairies, where Badiou et al. (2011) observed soil organic carbon concentrations (SOC) of 205 Mg C ha^{-1} in reference wetlands. However, in order to apply this carbon factor to wetlands in the Sheppard Slough Study Area we first needed to estimate the proportion of wetland basins that were class 3, 4, and 5. This was accomplished by aggregating the emergent and open water zone classes to represent wetland basins for both current and historical data in the study area. Wetland basins were then organized by size class for each epoch. A proportion of basins within each size class for the study were selected and classified as class 3-5 wetlands based on the size class specific proportion of class 3-5 wetlands in the supplemental wetland inventory.

The difference in SOC between the two epochs has been determined as an aggregation of each wetland sample for the entire watershed (net change). No attempt was made to look at differences at each individual basin as this would have been difficult to do given that we randomly selected features to represent a specific range of permanence classes. Although we estimate carbon stores in intact class 3-5 wetlands at 205 Mg C ha^{-1} (to a depth of 30 cm), not all of this carbon is lost when these systems are altered, degraded, or lost altogether. To conservatively estimate the amount of carbon re-emitted back to the atmosphere as a result of wetland loss in the Sheppard Slough

Study Area (specific to class 3-5 wetlands) we applied an SOC loss of 89 Mg ha^{-1}. This factor is taken from Badiou et al. (2011) and was estimated from the differences in SOC concentration between intact wetlands (205 Mg SOC ha^{-1}, 95 per cent confidence limits 171 – 246 Mg SOC ha^{-1}) and recently drained wetlands (116 Mg SOC ha^{-1}, 95 per cent confidence limits 99 – 136 Mg SOC ha^{-1}). This translates into a release of approximately 326 Mg CO_{2eq}. for every hectare of wetland loss. This estimate is conservative as it was derived from sites where wetlands were drained but remained in grassland cover. We would expect greater losses in SOC from wetlands that are drained and put into agricultural production or that are excavated and developed.

Results and Discussion:

Historic (1962) and Current (2005) Wetland Inventories

Historic and current wetland abundance and distribution (based on zones identified as Wetland-Emergent Vegetation and Wetland-Open Water) for the Sheppard Slough Study Area are illustrated in Figure 2. Size class distributions of wetland basins in the Sheppard Slough Study Area and the DUC Study Sites within a 150 km radius of the Sheppard Slough Study Area were very similar (Figure 3).

We determined the proportion of specific basin size classes that were deemed to be either seasonal (class 3), semi-permanent (class 4), and permanent (class 5) wetlands for the DUC Study Site wetlands (see Table 1). We then applied the size class factor to randomly selected basins for each size class in the historic and current wetland inventories for the Sheppard Slough Study Area. This allowed us to estimated class 3-5 wetland area for the Sheppard Slough Study Area. In both the Sheppard Slough Study Area and the DUC Study sites most wetland basins were less than 0.5 ha in size (approximately 90 per cent of basins). However the wetland area was comprised mostly of basins greater than 0.5 ha in size (Table 2).

Based on this exercise we estimate that in 1962 there were approximately 1,980 ha of wetlands (class 3-5) and this decreased to 1,484 ha in 2005, for a total change of 496 ha. This is equivalent to a 25 per cent loss in wetland area between 1962 and 2005 or approximately 0.6 per cent per year.

Assessment of Wetland Carbon Stores and change in Wetland Carbon Stores between 1962 and 2005

Applying an SOC pool of 205 Mg for every hectare of class 3-5 wetland in the Sheppard Slough Study Area we estimate that the total wetland SOC pool in 1962 was 405,818 Mg, and 304,276 Mg in 2005. As was the case for wetland area, SOC pools in both 1962 and 2005 were almost entirely related to wetland greater than 0.5 hectare in size (Table 3).

The estimated loss of SOC between 1962 and 2005 is 44,144 Mg. This is calculated based on the change in wetland area between 1962 and 2005 (decrease of 496 ha) multiplied by the average loss of SOC in drained wetland basins (89 Mg SOC ha^{-1}). This is equivalent to an emission of 161,832 Mg CO_{2eq}. The loss of SOC estimated here is likely very conservative. In regions such as the Sheppard Slough Study Area where wetlands were drained and either cropped or developed we would expect a larger change relative to those we estimated based on drained wetlands in grassland landscapes.

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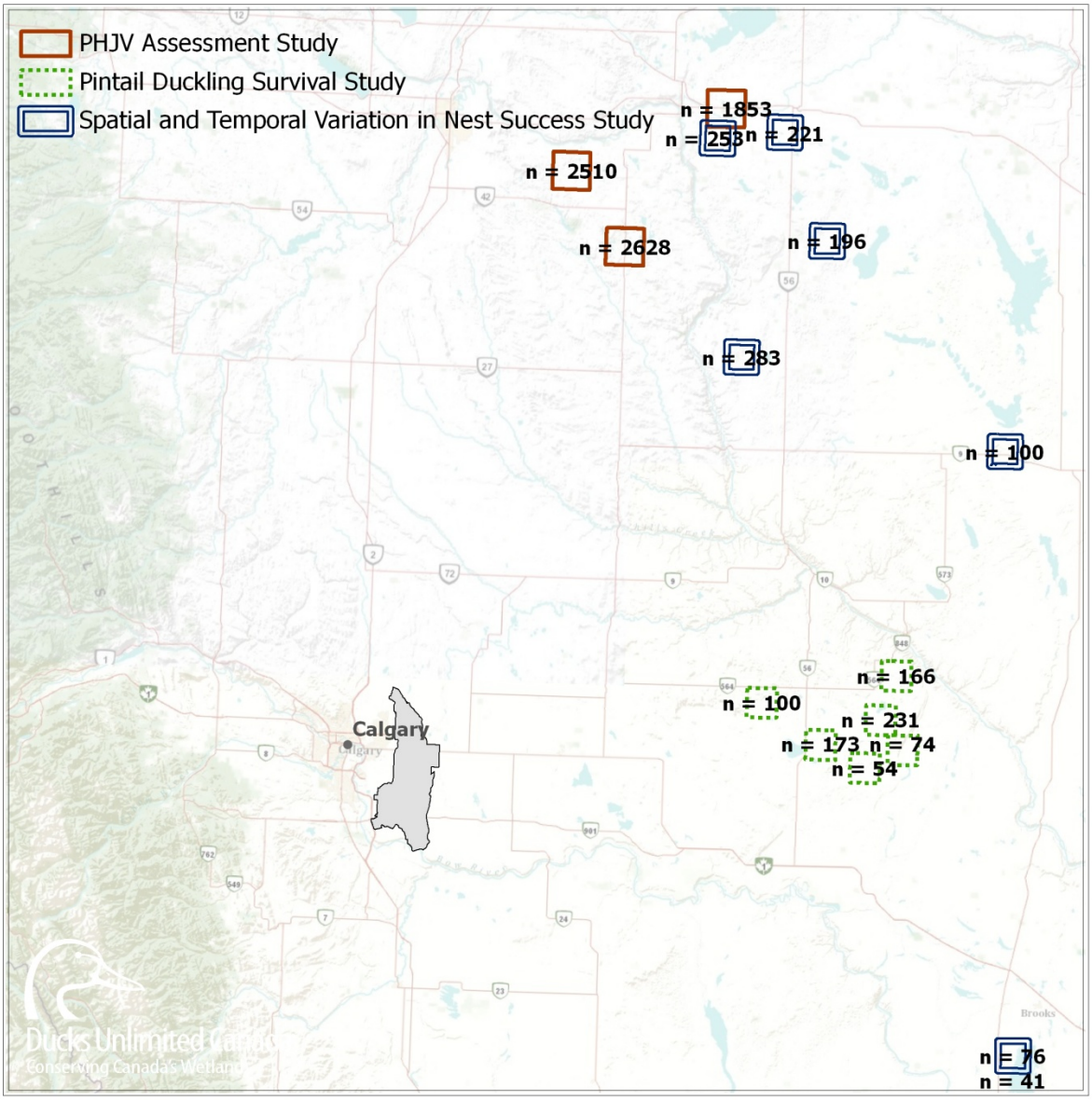

Figure 1. Location of DUC Study Site wetlands within a 150 km radius of the Sheppard Slough Study Area.

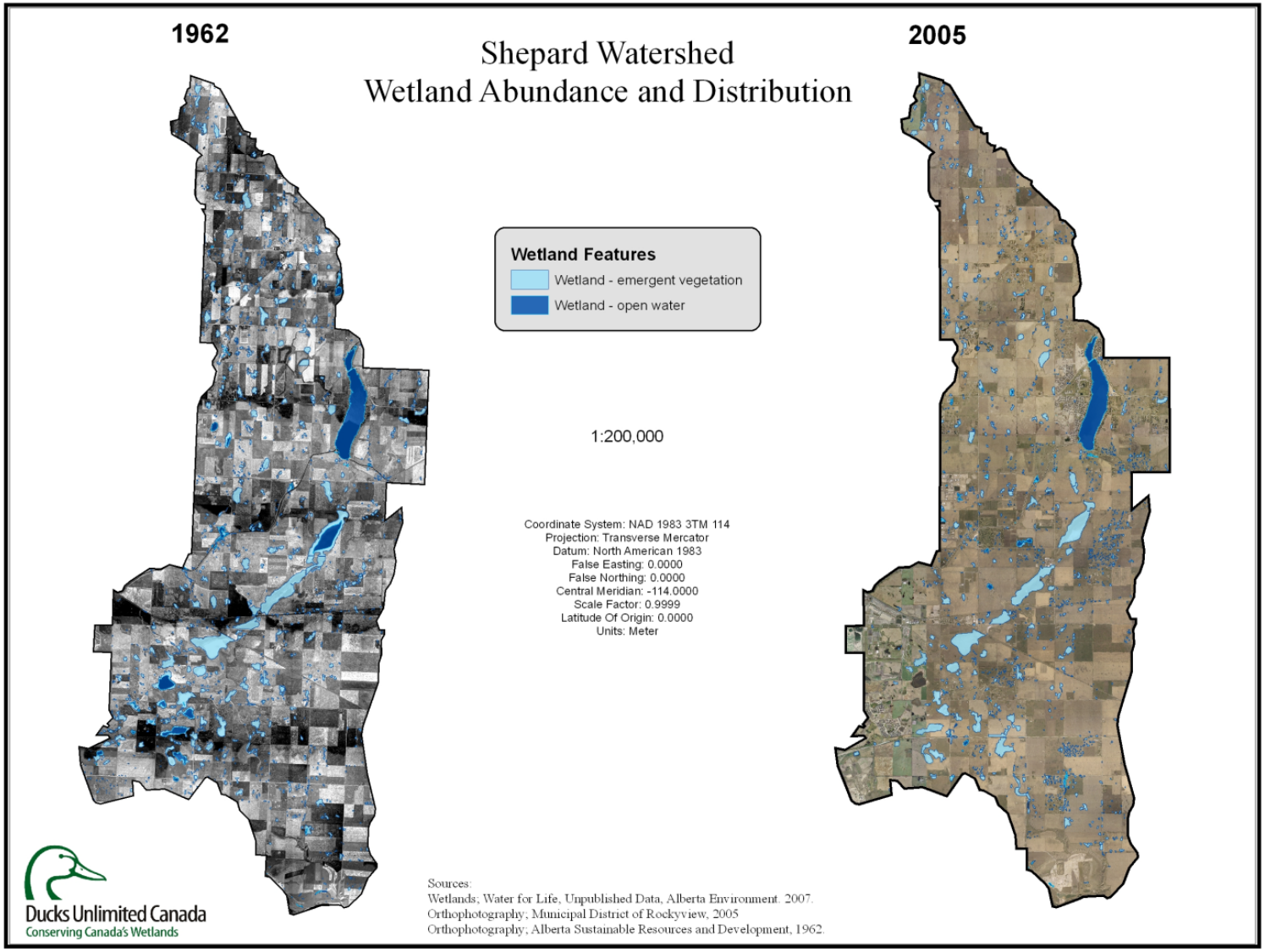

Figure 2. Historic and current wetland abundance and distribution in the Sheppard Slough Study Area.

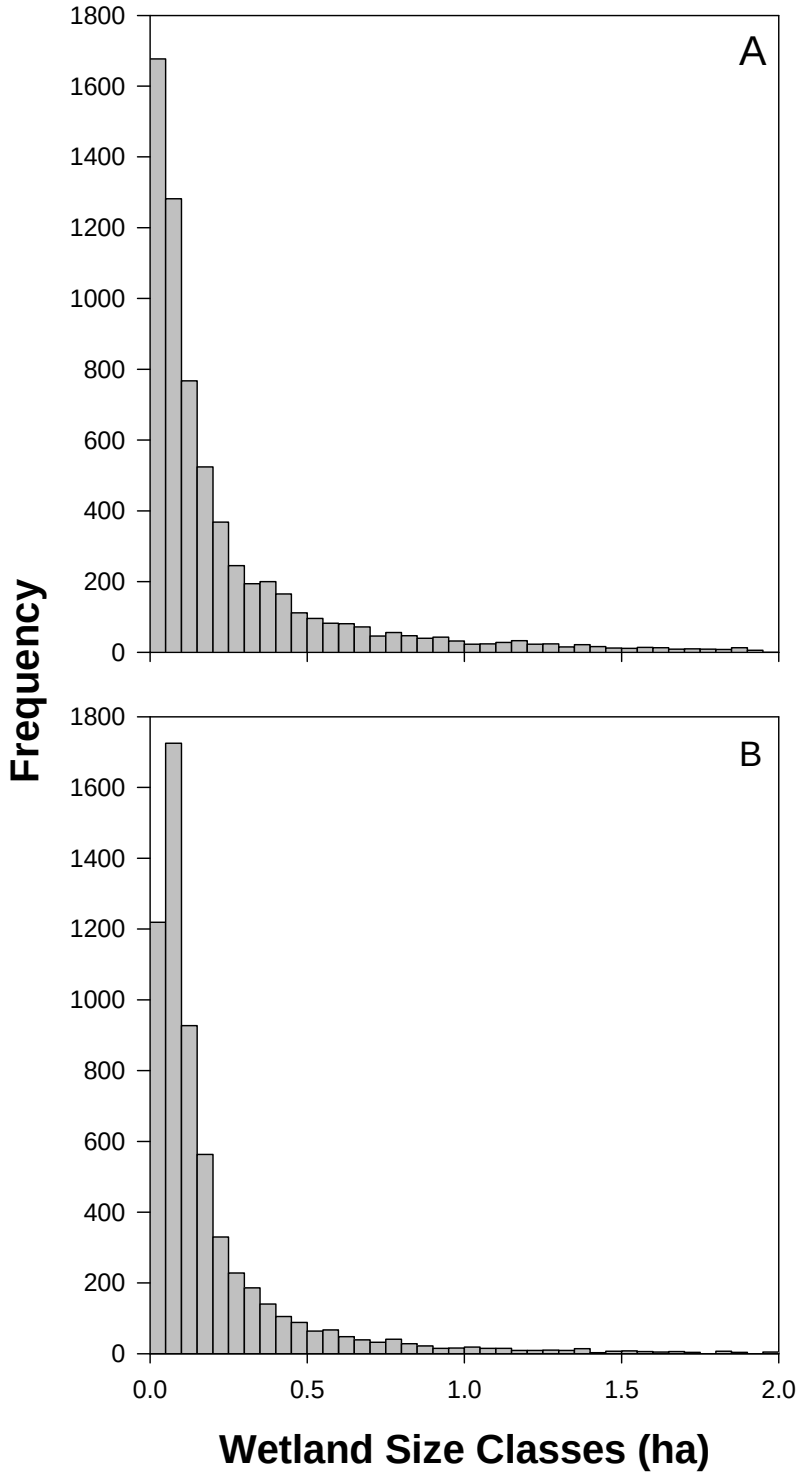

Figure 3. Size class distribution of wetland basins under 2 ha for A) DUC study sites and B) the Sheppard Slough Study Area .

Table 1. Area and frequency of wetland size classes for DUC study sites within a 150 km radius of the Sheppard Slough Study Area.

Size Class (ha)	Frequency	Wetland Area (ha)	Basins (%)	Area (%)	% of basins that are seasonal, semi-permanent, and permanent	% of wetland area that is seasonal, semi-permanent, and permanent
0.00-0.05	1,677	46	25.3	0.7	61	61
0.05-0.1	1,282	93	19.3	1.4	67	67
0.1-0.2	1,291	185	19.4	2.9	77	77
0.2-0.3	613	150	9.2	2.3	83	83
0.3-0.4	394	138	5.9	2.1	85	85
0.4-0.5	277	123	4.2	1.9	90	89
0.5-0.6	178	98	2.7	1.5	92	92
0.6-0.7	153	99	2.3	1.5	93	93
0.7-0.8	102	77	1.5	1.2	93	93
0.8-0.9	87	74	1.3	1.1	95	95
0.9-1.0	75	71	1.1	1.1	95	95
1.0-1.2	108	120	1.6	1.9	94	94
1.2-1.4	84	109	1.3	1.7	95	95
1.4-1.6	53	79	0.8	1.2	94	94
1.6-1.8	41	69	0.6	1.1	98	98
1.8-2.0	29	55	0.4	0.8	93	93
2.0-10.0	163	594	2.5	9.2	94	95
10.0-100	29	838	0.4	12.9	93	97
100-1000	3	512	<0.1	7.9	100	100
1000 and greater	2	2,945	<0.1	45.5	100	100

Table 2. Historic and current wetland area (class 3-5 wetlands) for basin size classes in the Sheppard Slough Study Area, estimated from the area distribution of class 3-5 wetlands at DUC Study Sites within 150 km radius of the Sheppard Slough Study Area .

Size Class (ha)	Class 3-5 proportion factor based on DUC study sites	1962 - estimated area of seasonal, semi-permanent, and permanent basins (ha)	2005 - estimated area of seasonal, semi-permanent, and permanent basins (ha)
0.00-0.05	0.61	2.4	6.1
0.05-0.1	0.67	10.6	19.5
0.1-0.2	0.77	35.2	42.5
0.2-0.3	0.83	35.5	29.0
0.3-0.4	0.85	35.3	32.2
0.4-0.5	0.89	32.8	27.9
0.5 and greater	0.95	1,827.8	1,327.1
Total for all	**-**	**1,980**	**1,484**

Table 3. Historic and current wetland SOC pools (Mg) for basin size classes in the Sheppard Slough Study Area.

Size Class (ha)	1962 – SOC stored in Wetlands (Mg)	% of total wetland SOC pool	2005 – SOC stored in Wetlands (Mg)	% of total wetland SOC pool
0.00-0.05	485	0.1	1,243	0.4
0.05-0.1	2,174	0.5	3,994	1.3
0.1-0.2	7,222	1.8	8,719	2.9
0.2-0.3	7,279	1.8	5,955	2.0
0.3-0.4	7,227	1.8	6,599	2.1
0.4-0.5	6,732	1.7	5,719	1.9
0.5 and greater	374,699	92.3	272,047	89.4
Total for all	**405,818**	**100**	**304,276**	**100**