JAMES W. SEWALL COMPANY / Since 1880

An integrated team of geospatial, engineering, and natural resource consultants, Sewall partners with clients to create practical, sustainable solutions.

REPORT

Merrymeeting Bay-Aquatic and Upland Habitat Assessment Update - 2018

Prepared for:

Friends of Merrymeeting Bay

Abby marsh along Kennebec – Point of View Helicopter Services, LLC

Prepared by:

Martin Curnan, LPF

June 25, 2019

85313L

Offices nationwide
sewall.com
800 648 4202
info@sewall.com

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

APPENDIX

1. INTRODUCTION

In May of 2018, the Friends of Merrymeeting Bay (FOMB) commissioned James W. Sewall Company of Old Town, Maine to provide technical support for aerial photography, mapping, and analysis of trends in the Bay and surrounding half-mile buffer area. Previous photo-interpretation studies of the Bay were conducted in 1956, 1961, 1966, and 1981 (Spencer, 1966; Anderson, 1982). In 1998, FOMB hired Sewall,in the first project of its kind; to fly aerial photograpy of the Bay using color infra-red film, conduct photo interpretation for aquatic and upland cover types as well as anthropogenic structures, create a new GIS base integrating the earlier years 1956 and 1981 and perform an analysis of trends for the period. (Sewall, 2000). In 2009, FOMB and Sewall repeated the work and in another study updated the vegetation and land use data and created a new baseline GIS with consistent horizontal accuracy across the study area. The following is a discussion of the results of the latest update to the study, which is based on aerial photography flown by Sewall in July 2018. This report first discusses aspects of the methodology (field method, orthophoto production, photo interpretation, and GIS). It then presents summary figures, tables, and a brief discussion of changes in the study area over the five study years, with primary emphasis on the latest period –2009 to 2018. Maps, an ArcGIS geodatabase, an ESRI ArcGIS summary .mxd file, and a comprehensive data table in Excel spreadsheet format accompany this report on DVD and will provide a sound basis for further analysis.[1]

[1] Appendix B of this report describes the study products delivered to FOMB with this report.

2. STUDY AREA DEFINITION

All 2018 photos were classified for the Bay proper and its six tributary rivers and adjacent wetlands to the head of tide, as well as upland types in an area within 1/2 mile of the Bay. Study areas of the various years are also restricted by the limits of aerial photo coverage in the various years. Figure 2.1 shows the study area extent.

Figure 2.1. The study area as defined by the intersection of initial five years of photo coverage, and the definition of subsections.

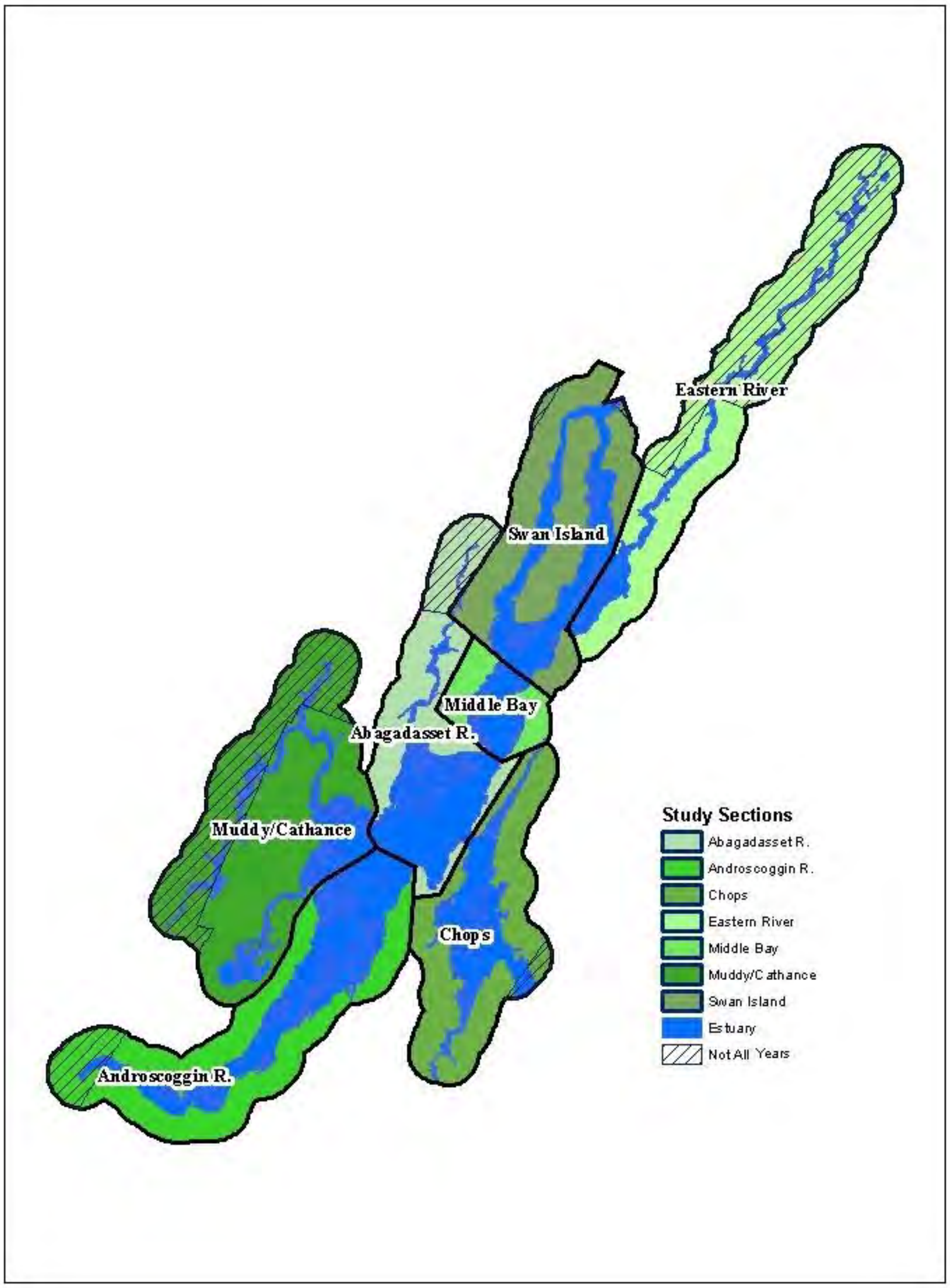


PHOTO TIMES AND WATER LEVELS AT FLIGHT TIME

The first step in the project was capture of photography. Digital color infrared (IR) imagery was flown at low tide with a sun angle of less than 50 degrees at a scale of 1 inch = 1000 feet, on July 30, 2018. Flight timing was coordinated with Ed Friedman, Chairman of the Friends of Merrymeeting Bay, being careful to avoid hours adjacent to solar noon: flights under these conditions at low tide tends to have high reflectance back from wet surfaces, which masks the vegetation[2].

To document tide levels for the later trend analysis section of this report, the times of photography and water levels[3] for all four dates are shown below:

1956 Photography

Flight Lines 1-8 taken on August 25 between 10:00 am and noon EST - hourly MLLW = 1.03, 0.42, 0.55 ft

Flight Lines 9-13 taken on August 27 between 11:00 am and 1:00 pm. EST – hourly MLLW = 1.38, 0.73, and 0.48 ft.

1981 Photography

Taken on August 18 at a mean time of 9:00 am. EST - MLLW = 0.21 ft

1998 Photography

Taken on August 9 at a mean time of 8:50 am EST. The actual flight line times were:

Line 1	9:12 to 9:13	Line 5	8:43 to 8:47	
Line 2	9:08 to 9:09	Line 6	8:34 to 8:39	- MLLW 9 a.m.= – 0.21 ft
Line 3	9:01 to 9:05	Line 7	8:26 to 8:31	
Line 4	8:52 to 8:57			

2009 Photography

The 1:12000 CIR photos were flown on August 6, 2009 at a mean time of 9:25 am EDT.

The mean times by flight line were (EDT, a.m.):

Line 1	9:25	Line 5	9:32	
Line 2	9:17	Line 6	9:39	- MLLW 9 a.m. = 0.47 ft
Line 3	9:09	Line 7	9:43	10 a.m. = 0.83 ft
Line 4	9:00			

---

[2] Note that this recommendation of flight timing is optimal for vegetation but not for buildings, roads, and other features that may be overtopped or shaded by trees. Therefore, building and road digitization from the orthophotos has some limitations. This applies to the photography of all study years.

[3] Water Levels: These indications of relative water levels are from the data collected at the gauging station in Bath, ME (Sturgeon Island – Latitude 43° 59’ N, Long 69° 50’ W), for which historic readings were obtained from the https://me.usharbors.com/monthly-tides/Maine-Midcoast/SturgeonIsland / for all flight times. MLLW = Mean Lower Low Water.

2018 Photography

An index of flight line and photo numbers with photo-center locations is provided in the GIS data and in Appendix C. The 1:12000 digital IR photos were flown on July 30, 2018 at a mean time of 9:23 a.m. EDT.

The mean times by flight line were (EDT, a.m.):

Line 1	8:53	Line 5	9:28	
Line 2	9:00	Line 6	9:38	- MLLW 9:37 a.m. = 0.20 ft
Line 3	9:08	Line 7	9:47	9:43 p.m. = 0.60 ft
Line 4	9:18	Line 8	9:55	

3. DATA PROVIDED BY THIS STUDY

ORTHOPHOTOGRAPHY

Orthophotos were created using airborne GPS data and IMU exterior orientation parameters from the aerial flight, a 10-meter digital elevation model from the National Elevation Dataset (USGS), and Orthomaster software from Inpho gmbh. The orthophoto resolution is 0.3 m, which is a higher resolution than the 0.5m resolution used on the 2009 project. NIR and RGB Orthophotos were provided on a thumb drive in a 5km x 5km tile structure in JPEG2000 compressed format.

STUDY SECTIONS AND TOWNS

Successive study years covered different portions of the Bay and surrounding area. Original studies were based on aerial photography that covered both the Bay and substantial upland areas, but the studies themselves were of the Bay only. The 1998 study extended the area to include a half mile buffer around the Bay as far as photographic coverage from the earlier years permitted. The polygon feature class Study_Sections defines the outer boundary of the maximum coverage area. It also includes an approximation of the boundaries of the areas that were used in the earlier Maine Inland Fisheries and Wildlife studies (Spencer, 1966; Anderson, 1982). In order to allow comparison by sub-region across the time periods, these boundaries were extended into the half-mile buffered areas adjacent to the Bay.

Figure 2.1 shows the section boundaries as well as the relationship between the four years' effective study areas. Crosshatching indicates the area where there are less than 4 years of photo coverage. All four-year tables and charts in the trend analysis section refer to non-crosshatched areas. Analysis tables and charts relating only to 1998, 2009 and 2018 use the entire area. Also depicted in Figure 2.1, in blue, is the area referred to in both this and the previous study as "Estuary" –the Bay and rivers and the wetlands and islands bordering them.

Also provided is the polygon feature class Intersection_Sections_StudyArea_Towns. The July 2007 version of the Maine Office of GIS town boundaries were added by intersection to the Study_Sections to create this polygon set consisting of study sections and towns.

VEGETATION AND LAND USE DATA

Methods used in creating the vegetation and land use datasets have changed over the years. The base that had been used in 1998 was the most current USGS mapping (1984). Transfer from aerial photos to this base was controlled by matching photo features such as roads to features on the USGS map using a monoscopic transfer device (zoom transfer scope or sketchmaster). This control was adequate in areas of sufficient matching detail, but less so in undeveloped areas and least adequate in the Bay proper. In the 1998 study, the detail captured against the USGS base was used as control in the capture process for features interpreted on the earlier photos of 1956 and 1981. In 2009, where the orthophoto base was used, the 1998 base was superseded by the orthophoto base. To effect consistent horizontal positioning of features, all work was controlled directly by the new orthophoto base.

The 2018 project built upon the much improved dataset developed in 2009. Starting with the polygons created in 2009 geometry revisions and interpretation occurred against a new orthophoto based developed in 2018. The primary method for the initial revisions to polygon geometries was by means of heads up digitization on ArcMap10.4. Upland area polygons only required changes when type lines moved by a specified amount or a new interpretation was appropriate that required breaking up or merging polygons. The wetland areas, which are much more dynamic especially in the Bay, required all new polygons to be created. After initial polygon geometry revisions and updates were complete, photo interpretation (of land use and vegetation?) occurred.

The raw scans of aerial images were set up for stereo viewing on a DATEM softcopy workstation using Summit Professional v 7.4 (DAT/EM Systems International). This system allowed for further direct editing/digitizing of polygon boundaries and addition of interpreted attributes while viewing in a 3-D environment.

An ArcGIS scripted menu system with all appropriate interpretation codes controlled data entry during interpretation to optimize coding efficiency. The interpreted categories were set up to allow later expansion by computer routine into appropriate component codes of land use class, land use sub-class, vegetation, and forest cover type. Polygon boundaries and fill color were set in ArcGIS so that it was easy for the interpreter to tell visually when labeling was complete.

All polygons were viewed individually in the 3-D environment by Marty Curnan (wetland areas) and Stephanie Phillips (upland areas), both experienced photo-interpreters trained by Lyman Feero who interpreted the last two project years. Polygon boundaries were revised as necessary and the most appropriate attribute value(s) assigned based on interpretation.

GPS-tagged points with comments on vegetation were collected on orthophotos in Avenza maps by Marty Curnan and Ed Friedman, who visited sites by helicopter within a few days of the aerial photography as well as several weeks later after the initial photo interpretation had occurred. These points allowed the interpreters to establish familiarity with signatures of the vegetation classes on this set of aerial photography. Fine tuning and final classifications of the vegetation types occurred after the second helicopter site visit.

Upland land use was classified using a modified version of Anderson's (1976) classification, with alphabetic rather than numeric codes and with sub-classes added as deemed necessary. As in 1998, forested uplands were broken down into the land use subclasses softwood, mixed wood, and hardwood as well as typed for height and density. In 1956 and 1981, the forest land use type was not subdivided into subclasses.

Wetlands were classified as "WET" land use and also typed for class and sub-class under the Cowardin *et al* (1979) wetlands classification system. The Bay's emergent vegetation areas were sub-classified for the same target species classes as were used in previous studies (cf. Spencer, 1966). A summary of all codes is provided in Appendix A.

Standards for classification were the same as in previous years. In classifying emergent vegetation, a vegetated area was given a single species code if that species covered 70% or more of the area. Density of the coverage had to be at least 30% for an area to be considered vegetated. Areas with lower vegetation density than 30% were classified in terms of the substrate (silt, sand, rock, open water). If there was less than 70% coverage of one species it was classified as mixed.

In silt and sand areas, the water line is very difficult to discern, but there is usually a clear break at the edge of the silt or sand where deeper water appears to begin. Silt and sand were therefore interpreted when they could be distinguished even if submerged.

A new method used this year was the creation of a NDVI (Normalized Difference Vegetation Index) raster from the near-infrared and red bands of the captured imagery and utilizing it to better delineate submerged aquatics which are sometimes hard to distinguish under water. This approach may have been a contributing factor to the increase in area mapped as submerged aquatics.

Following completion of interpretation, polygons were checked in an ArcMap workstation environment for completeness of attribution and correct topology. An updated version of the routine that was used in 2009 to re-code the interpreter code (ALPHA) into the various vegetation, wetlands, and forest cover codes was then run.

Polygons resulting from the above steps were imported into a work version of the deliverable geodatabase in the projection system of the 2018 data (UTM, Zone 19, NAD83, Meters) and further reviewed to locate any incorrect coding. A systematic review was conducted of features assigned to the estuary category to reconcile the differences between years and make it consistent across years. The five study years were then combined using the ArcGIS UNION tool. Following this review, the analysis overlay was re-created.

Attribute Codes for the Vegetation and Land Use Feature Class (MMB_18_Veg_LU)

Attribute names and code values are essentially the same as for the earlier years of data with the only minor addition being the addition of the code "I" for three square as previously mentioned. Attribute names and their codes are provided in Appendix A.

Building Procedures and Data Description

A buildings data set is included in the study as a way to document development changes. The 2018 data layer was created with attributes that indicated if a building was present in 2009 or not. Like 2009, it also includes points for buildings that were removed between 2009 and 2018. The method of building data capture was as follows.

Building points from 1998 were imported to a working file. In an ArcGIS 10.4 editing environment with orthophoto backdrop, the study area was systematically reviewed by a photo-interpreter at relatively large scales (approximately 1:3000, with a typical residential building showing up at a size of about 0.2 cm). The building point symbols were set up so that as a building was visited and attributed as to its presence in 2018, the symbol changed to reflect the newly assigned value. In this manner all areas were visited and building points edited for 2018 status.

When a building was identified in the 2018 imagery that was missing from the 2009 dataset, historical imagery was checked via Google Earth Pro to determine if in fact it was a new building or just missed in prior years. Due to the timing of imagery capture, strong shadows are present that can easy hide buildings located within dense tree cover. If a building was determined to be missed, it was captured with a new point attributed with the IN_2009 as 'YES'. This method allowed for the data to be improved while ensuring that these missed buildings would not falsely count towards the number of new buildings totaled for the 2009 to 2018 period.

The "maybe" category was used when there was a 2009 point, but due to tree cover and shadow, it was not possible to be certain from the orthophoto of the current presence of the building. A full review was conducted by an additional interpreter of all the "Maybe" locations. As a result of this review, the buildings indicated with this status may be considered "probable" but not certain. Building digitizing was done with a size criterion of approximately 15' square. No distinction beyond this minimum size criterion was made as to building type or size.[4]

[4] 2009 procedures differed from those of earlier years in retaining points for buildings removed since the previous study year. The attributes of the 2009 buildings make it possible to distinguish new from old buildings - not possible with the simple point data of the previous years, which showed only buildings current at the time. See Sewall (2000) for a

Road Procedures and Data Description

Road features in the 2009 study were positionally adjusted versions of the E911 Maine data and then updated to include new public roads and longer private access roads. The 2018 study started with the roads created in 2009 as a base and then used a combination of the new imagery and the most recently available version of the MEDOTPUBRDS roads data from the Maine Office of GIS to make updates. Most of these roads include road name information in the attribute table. Roads present in 2009 were attributed as such to allow for identification of new roads.

In an ArcGIS 10.4 editing environment with orthophoto backdrop, the road centerlines in the study area were systematically reviewed by a GIS technician at relatively large scales (approximately 1:3000 – larger if necessary). Roads seen to be off-center relative to the orthophotos at this scale were adjusted to match the approximate centerline as shown on the orthophotos. In a follow-up phase, all areas of the map were visited to determine completeness of road coverage (using the 2009 roads for comparison), and centerlines added where it was possible to discern road rights-of-way on the orthophotos. Roads were also assigned a class value by reference to the 2009 road classes.

Vegetation and Land Use Analysis Procedures and Data Description

A single polygon overlay called Union_18_09_98_81_56_Section_Town was created by performing a Union operation between all five years' vegetation/land use feature classes and the data set Intersection_Sections_StudyArea_Towns. A new area in acres attribute, AcresX, was added to the attribute list of the new union feature class and populated with the area of each polygon. A framework for reporting on the data relationships was created by exporting this attribute table to an Excel spreadsheet called Union_18_09_98_81_56_Section_Town.xls. This spreadsheet, one of the delivered products, provides convenient pivot table analysis and charting functionality that can be used to explore relationships in the data.

The 2018 study used a data capture methodology that compensated for photo distortion factors in a manner that ensured consistent variation in horizontal error across the study area. While this was not the case for the earlier years prior to 2009, an adjustment of the data for earlier years to the new base was beyond the scope of the 2018 study (and probably not practicable, in fact). This means that there are "slivers" in the vegetation/land use polygon overlay resulting from the shift of boundaries due to differences in spatial base, rather than to actual change in the polygon's land use or vegetation class. Some percentage of the acreages changing category from year to year are a result of the spatial adjustment, and some from the greater detail of 2018's interpretation. These effects were evaluated both visually and analytically.

A framework for analysis of the effect of the spatial base change on trend analysis was created by linking to each 2018 polygon a cross-reference table showing the percent of each 2009 land use

---

description of the procedure for digitizing buildings for 1956 and 1981 (the source for these was primarily USGS data), and 1998.

class intersected by the polygon. Among other things, errors due to spatial adjustment showed as illogical transitions - for example from open water to forest. As expected, the areas affected most by spatial adjustment were within and along the Bay and the rivers (their linear character creates longer and therefore larger area "sliver" polygons due to the horizontal shift). The data framework allows for easy review of any particular transition by selecting the conditions and reviewing the specific areas in the GIS.

Recommendations for Future Updates to Vegetation/Land Use Polygons

The revised base created in 2009 and used in 2018 provides a framework for consistent accuracy. In the upland area land use interpretation, future updates will be able to start with this base polygon set and simply alter and interpret these polygons as necessary, changing boundaries only when they have moved by a specified amount, and breaking up or merging polygons when a new interpretation is appropriate. In the wetlands area, which is more dynamic, it will probably still be most appropriate to create new polygons as was the case with this 2018 study.

Future studies should review project boundaries prior to aerial imagery acquisition to allow for expanding the study area if necessary. During the 2018 study there was interest to extend the study area north along the Eastern River but sufficient imagery was not collected to warrant this expansion.

4. DISCUSSION OF TRENDS

While a detailed analysis of the data is beyond the scope of this report, a few basic tables have been produced to show major changes and provide examples of how the provided data can be used. The discussion parallels the analyses of the 1998 and 2009 studies. It first deals with overall trends in land use and then summarizes of some of the more significant trends in the vegetation, sand, silt, and open water within the Bay and its subsections. Appendix D provides example maps comparing the five study years in three areas of significant change.

LAND USE CHANGES FROM 1956 TO 2018 OVER THE ENTIRE STUDY AREA

Table 4.1 and Figure 4.1 summarize the changes that have occurred from 1956 to 2018.[5] They are based on the area of intersection of all five years' study areas (the area of Figure 2.1 that is not cross-hatched). The Land Use codes in this table and tables 4.2 and 4.3 are as follows: AGR – agricultural, COM – commercial; FOR – forest; IND – industrial; OW – open water; RES – residential; UHE – upland herbaceous; USS – upland scrub/shrub, and WET – wetland.

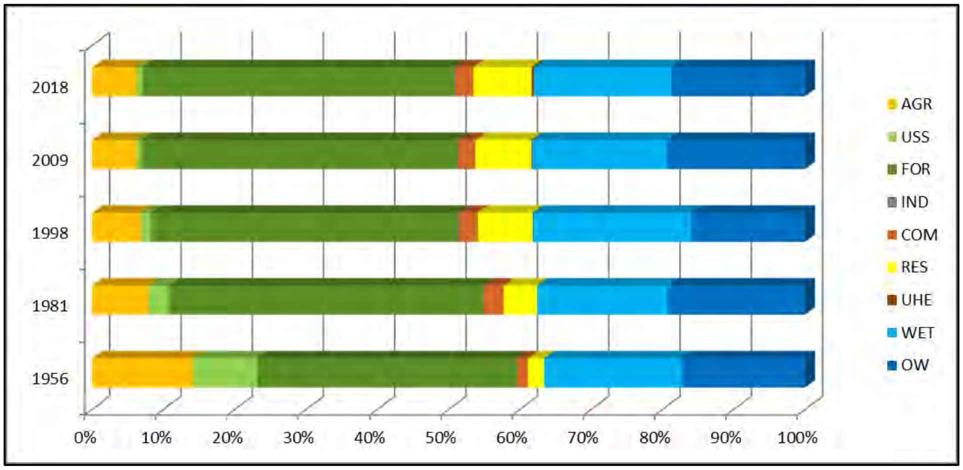
Table 4.1. Land Use Acreages and Percents for Five Study Years

Land Use Changes Across All Years - 1956-2018

	Acres					Percent				
Land Use	1956	1981	1998	2009	2018	1956	1981	1998	2009	2018
AGR	4,671	2,611	2,259	2,065	2,072	14.2%	7.9%	6.9%	6.3%	6.3%
USS	2,942	929	445	226	247	8.9%	2.8%	1.3%	0.7%	0.8%
FOR	12,020	14,536	14,208	14,607	14,429	36.5%	44.1%	43.1%	44.3%	43.8%
IND	7	27	79	39	40	0.0%	0.1%	0.2%	0.1%	0.1%
COM	498	913	829	772	832	1.5%	2.8%	2.5%	2.3%	2.5%
RES	748	1,547	2,537	2,581	2,683	2.3%	4.7%	7.7%	7.8%	8.1%
UHE		13	16	58	115	0.0%	0.0%	0.0%	0.2%	0.3%
WET	6,365	6,007	7,326	6,200	6,362	19.3%	18.2%	22.2%	18.8%	19.3%
OW	5,695	6,364	5,249	6,400	6,166	17.3%	19.3%	15.9%	19.4%	18.7%
Grand Tota	32,947	32,947	32,947	32,947	32,947	100.0%	100.0%	100.0%	100.0%	100.0%

[5] Note that in this and all subsequent tables rounding of results in table cells may result in marginal totals being one more or less than the values obtained by summing.

Figure 4.1. Percent of Acres by Major Land Use Code over Five Years.



This chart (figure 4.1) shows the trend from agriculture to forest and residential, with abandoned agricultural land trending through shrub-scrub and then changing to forest. In 2018 this trend has flattened with agriculture actually gaining several acres. Note also in Figure 4.1 that the sum of wetland and open water in the area of intersection of all five years is relatively constant (total percents are 36.2, 37.5, 38.2, 38.2, and 38.0 by respective year).

The transitions between 2009 and 2018 only are shown in Table 4.2. This table is based on all study area acres, a total of 42,218 (9,271 acres more than the area of intersection of all four years represented in table 4.1). 95% of the area stayed in the same class (diagonal). The dynamic nature of the Bay is highlighted in this chart with 505 acres of open water now wet and 284 acres of wet now open water.

Table 4.2. Transition of Land Use Acres between 2009 and 2018

Sum of Acres X	LUCLASS09									
LUCLASS18	AGR	COM	FOR	IND	OW	RES	UHE	USS	WET	Grand Total
AGR	2,588	1	28	0	6	38	0	20	8	2,688
COM	4	955	55	0	0	12	0	5	3	1,034
FOR	21	10	20,010	0	3	51	0	23	110	20,228
IND	0	0	1	48	1	0	0	0	1	51
OW	2	0	9	0	6,309	4	0	0	284	6,607
RES	33	6	250	0	0	3,495	3	16	5	3,807
UHE	3	1	25	1	0	19	59	29	0	137
USS	11	10	35	0	0	5	0	180	60	300
WET	8	4	78	0	505	8	1	16	6,745	7,365
Grand Total	**2,670**	**986**	**20,491**	**49**	**6,823**	**3,632**	**63**	**289**	**7,216**	**42,218**

Table 4.3 shows the land use classes for 1956 cross-tabulated against the land use classes for 2018. (The column showing as (blank) is the area that was typed in 2018 but not in 1956).

Table 4.3. Land Use Change from 1956 to 2018

Sum of Acres X	LUCLASS56									
LUCLASS18	**AGR**	**COM**	**FOR**	**IND**	**OW**	**RES**	**USS**	**WET**	**(blank)**	**Grand Total**
AGR	2,089	6	157	0	6	15	115	9	291	2,688
COM	135	365	352	0	3	58	102	16	4	1,034
FOR	1,906	152	12,578	0	59	211	2,556	405	2,362	20,228
IND	9	9	12	7	1	0	12	0	0	51
OW	8	3	142	0	5,330	10	15	1,007	92	6,607
RES	1,222	82	936	0	7	922	396	10	232	3,807
UHE	61	14	21	0	0	9	33	0	0	137
USS	123	10	39	0	1	7	32	57	32	300
WET	104	4	654	0	597	9	179	5,321	496	7,365
Grand Total	**5,658**	**644**	**14,891**	**7**	**6,005**	**1,241**	**3,439**	**6,824**	**3,510**	**42,218**

This table shows transition between classes from 1956 to 2018. The columns show associated acres for each class in 1956 and each row shows acres by class in 2018. For example the AGR column total indicates that 5,658 acres were classified as agriculture in 1956 and in 2018 about 37% remained in agriculture (2,089 acres), 34% (1,906 acres) became forest, 22% (1,222 acres) became residential. Another column of interest is upland shrub-scrub (USS), where 2,556 acres (74% of the category) of what probably was abandoned agricultural fields in the first stages of reversion to forest in 1956 was forest in 2018. The 3,807-acre 2018 residential category was 24% residential, 32% agricultural, 25% forest, and 10% upland shrub-scrub in 1956.

ESTUARY, RIVER AND ASSOCIATED WETLANDS COVER TYPE CHANGES

Although all aerial photographs were taken at or near low tide, there was variation in tide level between the five years. As noted in section 2 of this report, the lowest water levels at flight time were in 1998, while the other four years' tide levels were similar to each other. The last row of Table 4.4, which compares the acres in all years that were classed as Estuary = Yes, shows a total acreage varying between 12,061 in 1956 and 12,600 in 2009. The following tables and charts relative to emergent vegetation, silt, sand, etc. include this area only - the Bay or rivers and the wetlands adjacent to them.

The 1998 data on silt and sand reflect the effect of that year having the lowest tide of the five years. The sand and silt component is higher than in the other years, and open water correspondingly lower. With 2018 having a water level slightly higher than previous years (when accounting for submerged aquatic vegetation) the change to sand and silt is hard to compare. The trend to increased sand and silt that was observed by K.H. Anderson in 1982 and noted in the 2009 study is not maintained with a decrease from 1,107 acres to 990 acres from 2009 to 2018 which is likely more of a function of the higher water level and the increase in submerged aquatics. A consistent trend across all the years is the steady decline of pickerel weed.

Table 4.4. Estuary, River and Associated Wetlands Cover Type Acres

Acres

Component	1956	1981	1998	2009	2018
Forested Wetland	136	355	959	991	997
Scrub-shrub	1,238	1,315	608	694	707
A--Wild Rice	934	959	1,216	1,204	1,293
B--Yellow Water Lily	121	50	20	28	80
C--Sweet Flag	8	4	3	0.2	11
D--Softstem Bullrush	221	206	233	146	181
E--River Bullrush	13	9	28	28	14
F--Pickerel Weed	178	124	116	86	42
G--Mixed Emergents	2,278	1,782	1,351	1,516	1,148
H--Cattail	4	7	122	120	119
I--Three Square	-	-	-	-	114
High Tide Zone	53	7	45	8	1
ROCK	7	31	9	8	28
SAND	221	346	695	309	288
SILT	617	635	1,483	798	702
Submerged Aquatic Ve	336	178	438	264	637
Open Water	5,695	6,364	5,249	6,400	6,167
Total	12,061	12,372	12,574	12,600	12,529

Figure 4.2 provides a chart of the composition breakdown in percent of the total. When summing submerged aquatic vegetation with open water this chart suggests the 2018 water level as being slightly higher than previous study years.

Figure 4.2. Estuary, River and Associated Wetlands Cover Type Percents

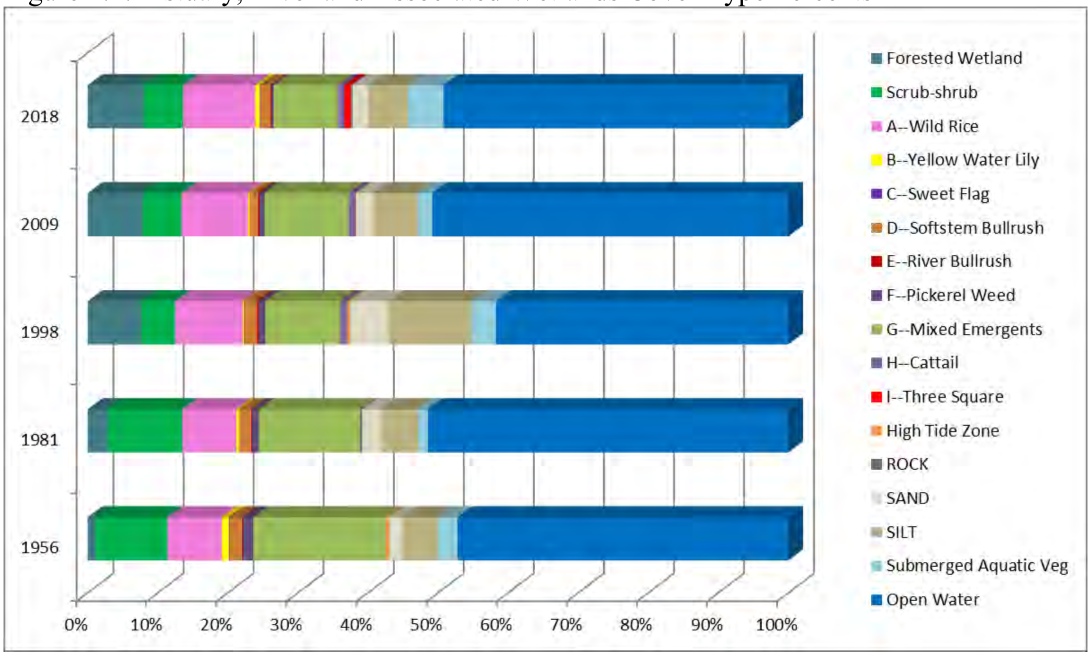
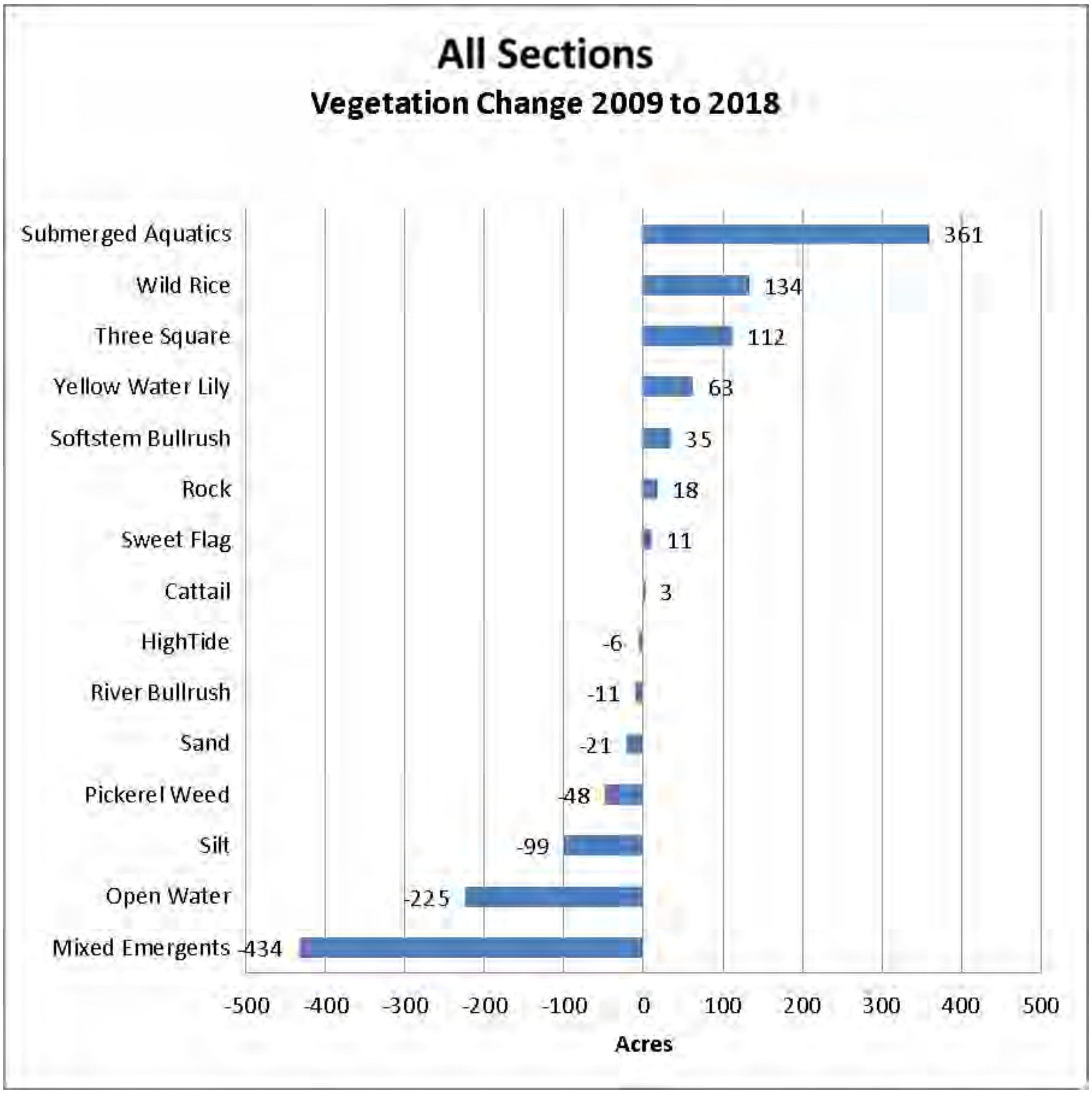


Figure 4.3 compares the 2018 vegetation against the 2009 study to view changes in Bay cover classes. Using these two years shows the slight increase of the water level showing an increase (136 acres) when accounting for both open water and submerged aquatics. Submerged aquatics increased the most (361 acres), more than offsetting the decrease in open water (-225acres). Wild rice also has increased (134 acres), along with the three square (112 acres not previously identified), yellow water lily(63 acres) and soft stem bulrush(35 acres), with a corresponding decrease in mixed emergents (-434 acres). Sweet flag, cattail, and river bulrush were all mostly unchanged.

Figure 4.3. Changes across All Sections 2009 to 2018

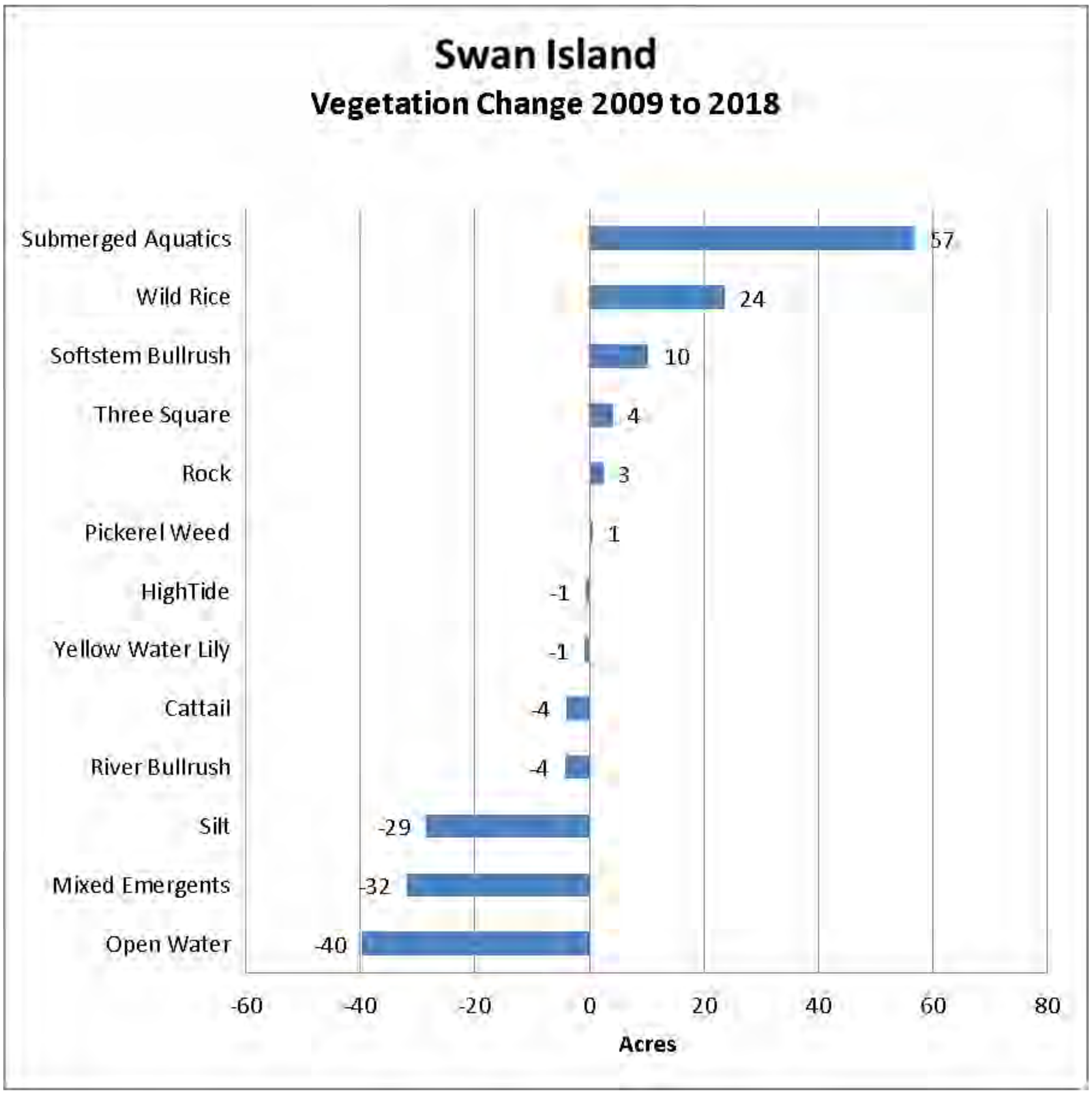


VEGETATION CHANGES FROM 2009 TO 2018 BY SECTION

The following charts depict change in cover components within the Bay between 2009 and 2018 by study section, moving from north to south.

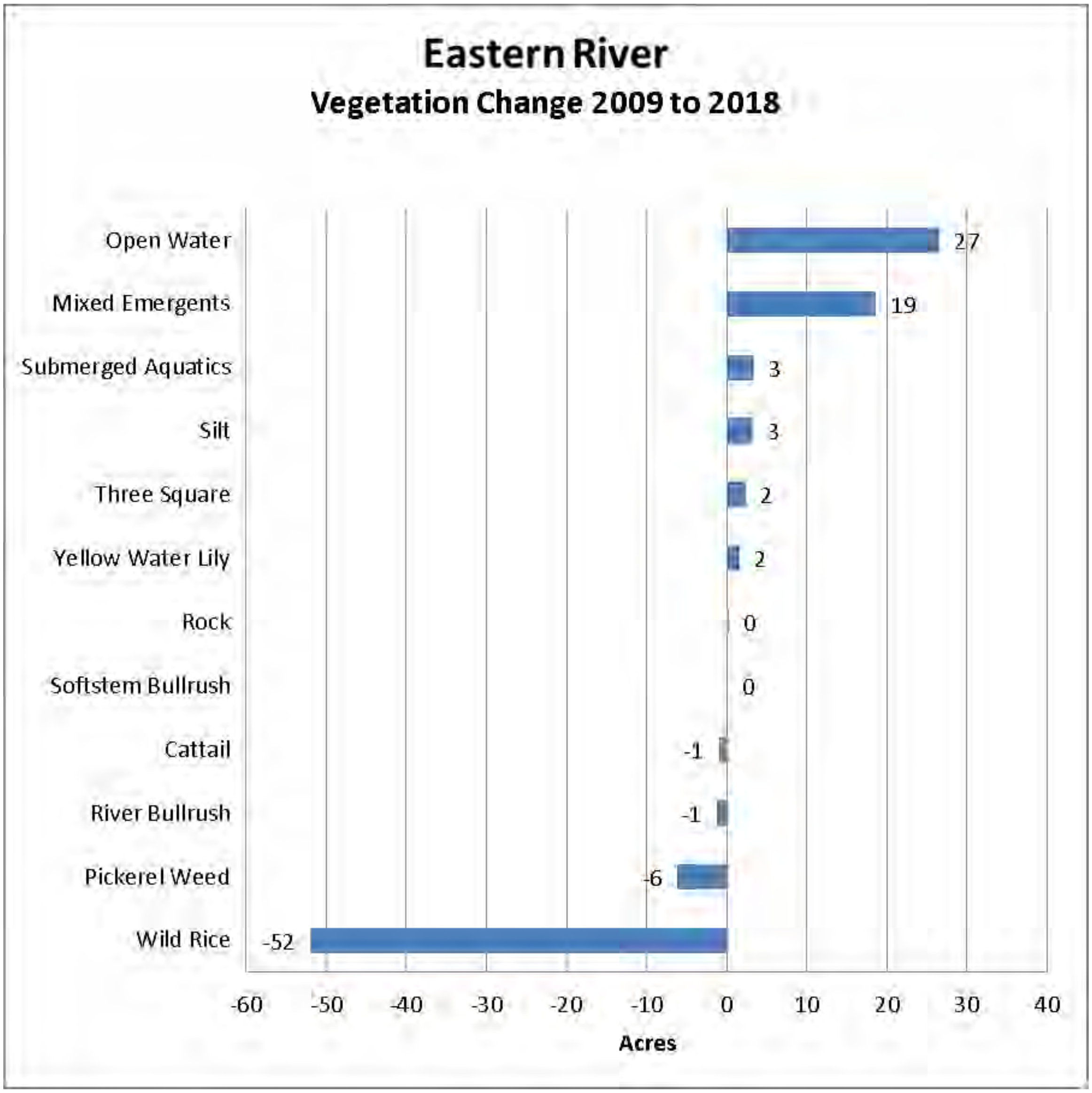
Swan Island

The tradeoff between wild rice (2018 is 24 acres greater than 2009) and mixed emergents (2018 is 32 acres less than 2009) is strong in this northern section. Submerged aquatic vegetation shows the strongest increase (57 acres), but this is attributable to the higher 2018 water level. The change in all emergent vegetation in this section was a slight decrease of 2 acres.



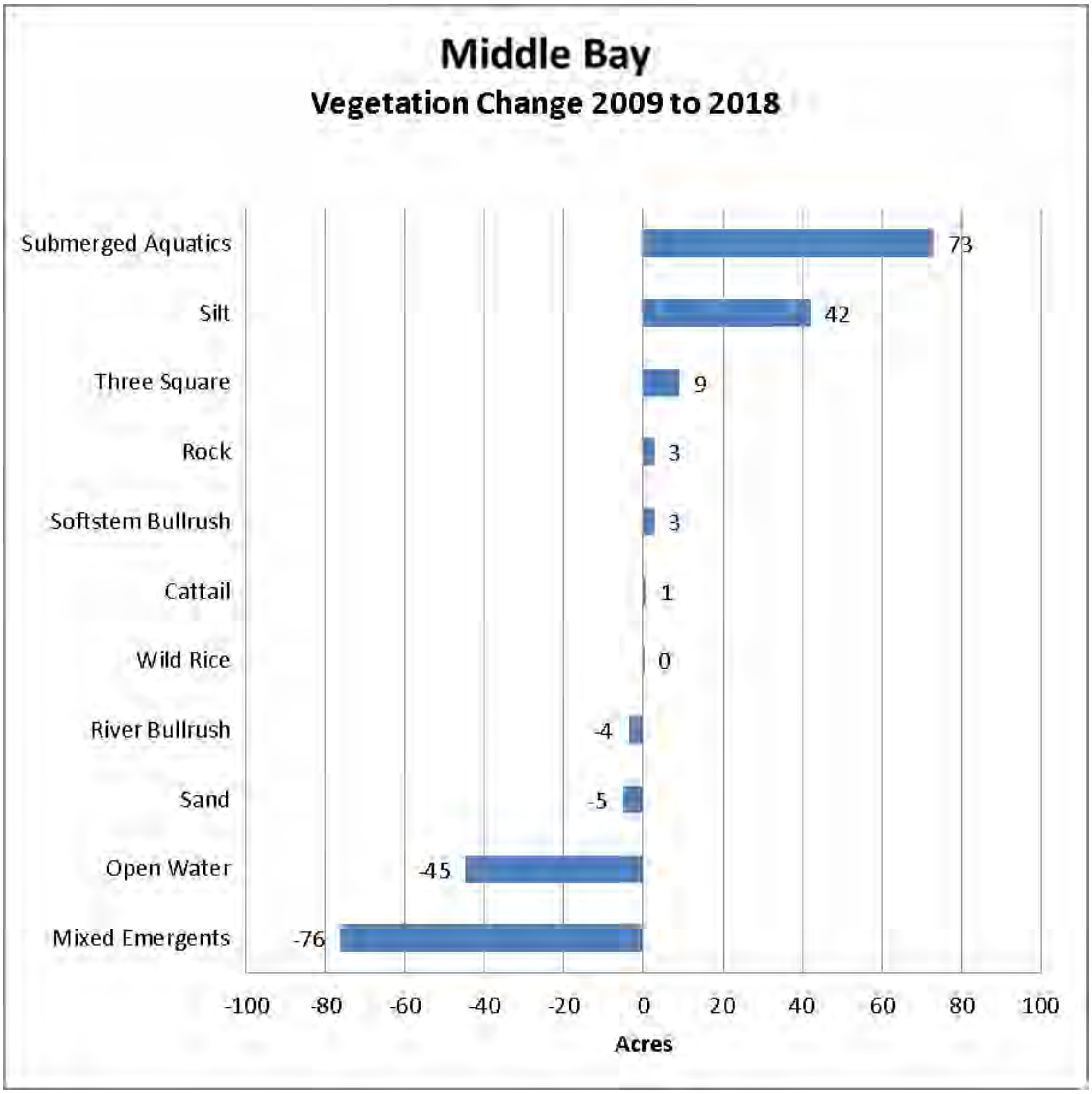
Eastern River

This subsection saw a decrease in wild rice (-52 acres) and an increase in mixed emergents (19). The higher water level of the water is shown here with an increase of open water (27acres). The decrease in total emergent vegetation in this section was 34 acres.



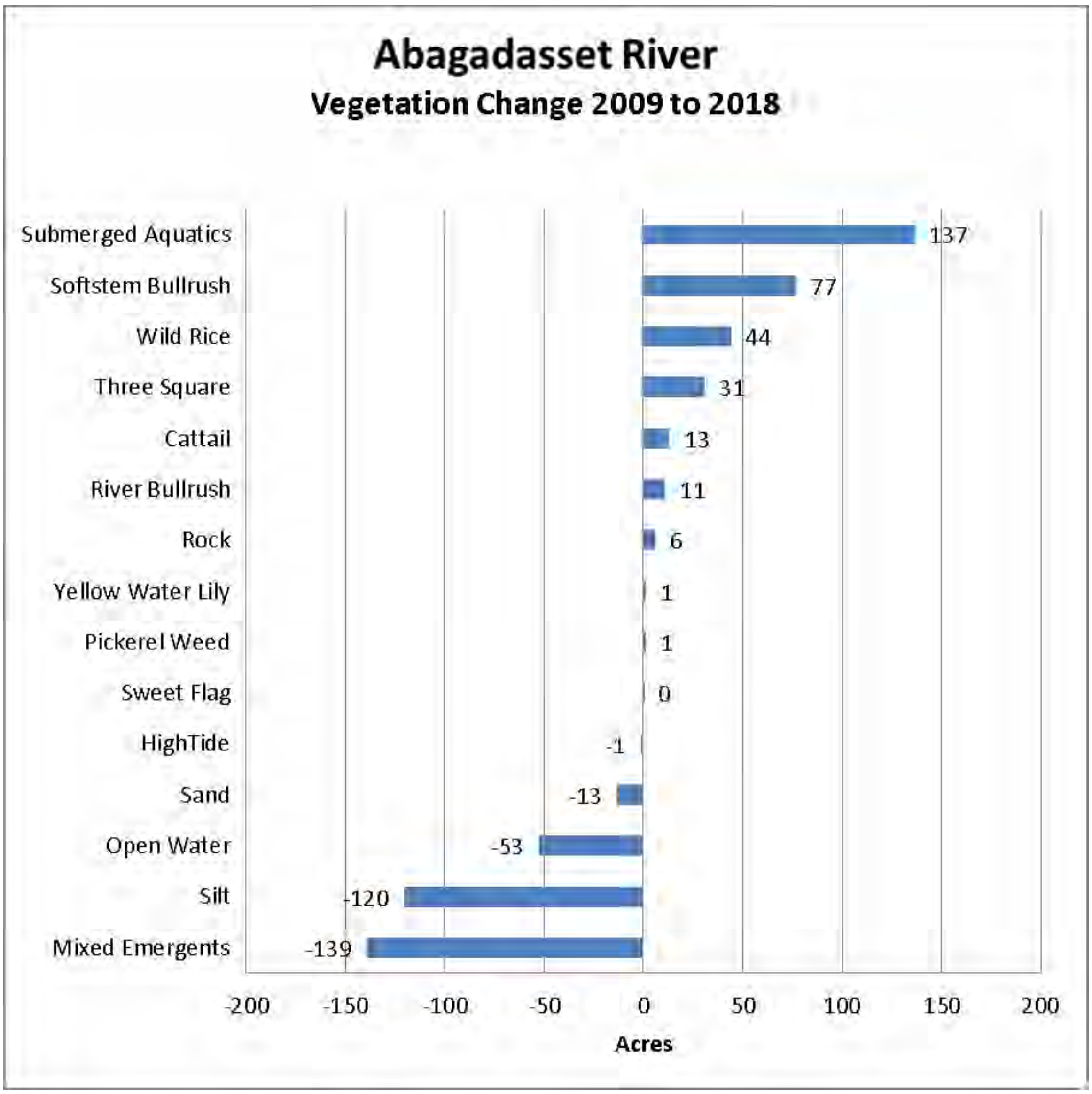
Middle Bay

The primary increase other than the study wide increase of submerged aquatics (73 acres) was silt (42 acres), probably a better reflection of actual increase than the 197 acres of 1998, which reflected the lower water level, but an increase nonetheless. A decrease was observed for mixed emergent vegetation (-76 acres). The decrease in total emergent vegetation in this section was 67 acres.



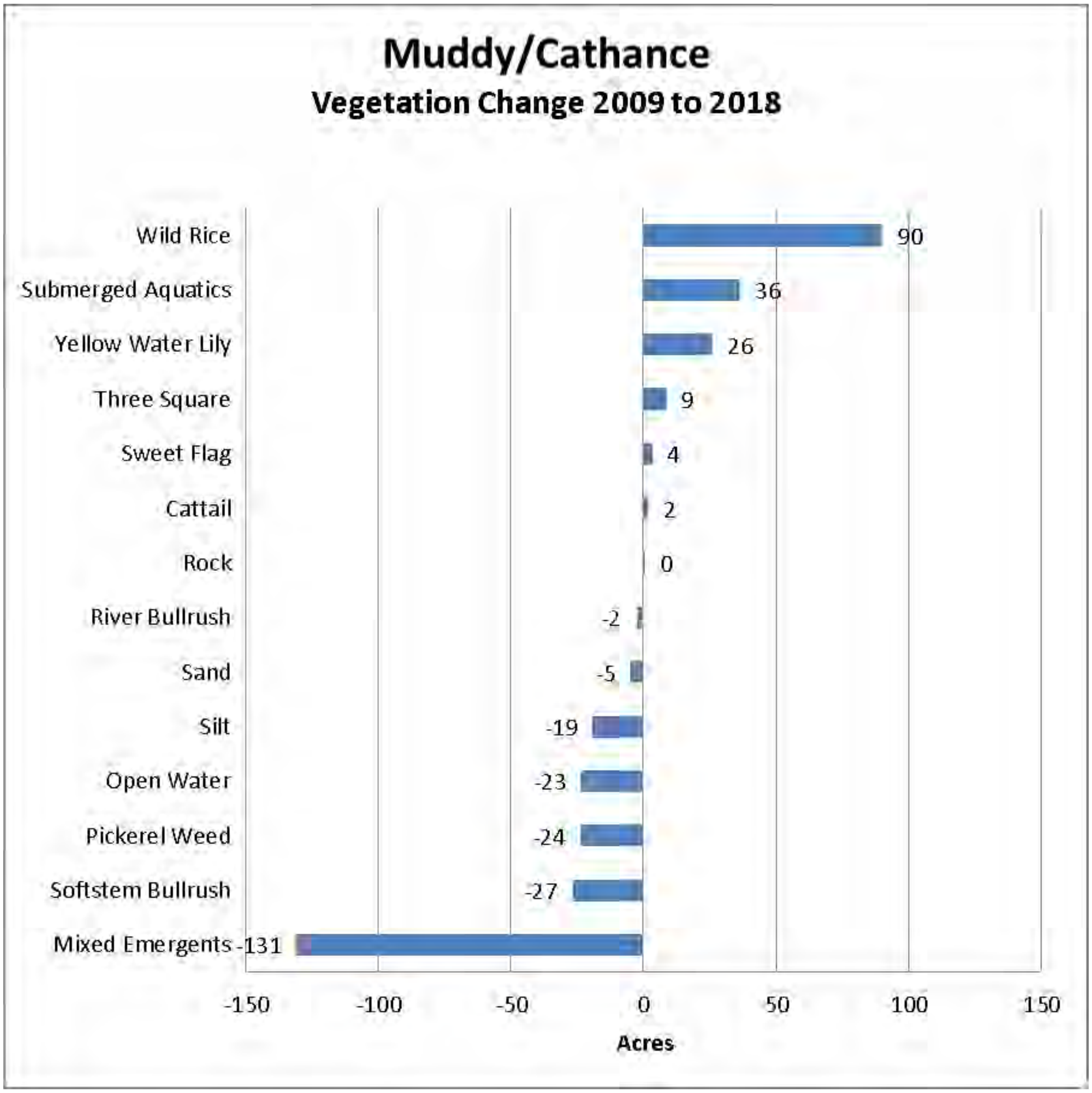
Abagadasset River

The primary increases other than the study wide increase of submerged aquatics(137 acres) was softstem bullrush (77 acres), wild rice (44 acres), three square (31acres), cattail (13 acres) and river bulrush (11acres). Much of this increase can be attributed to more detailed delineation in 2018 and the corresponding decrease of mix emergent (-139 acres). The increase of cattail was noted with all areas expanding in size. Three square was note previously delineated and was likely included in the mixed emergent in earlier studies. The increase in total emergent vegetation in this section was 45 acres.



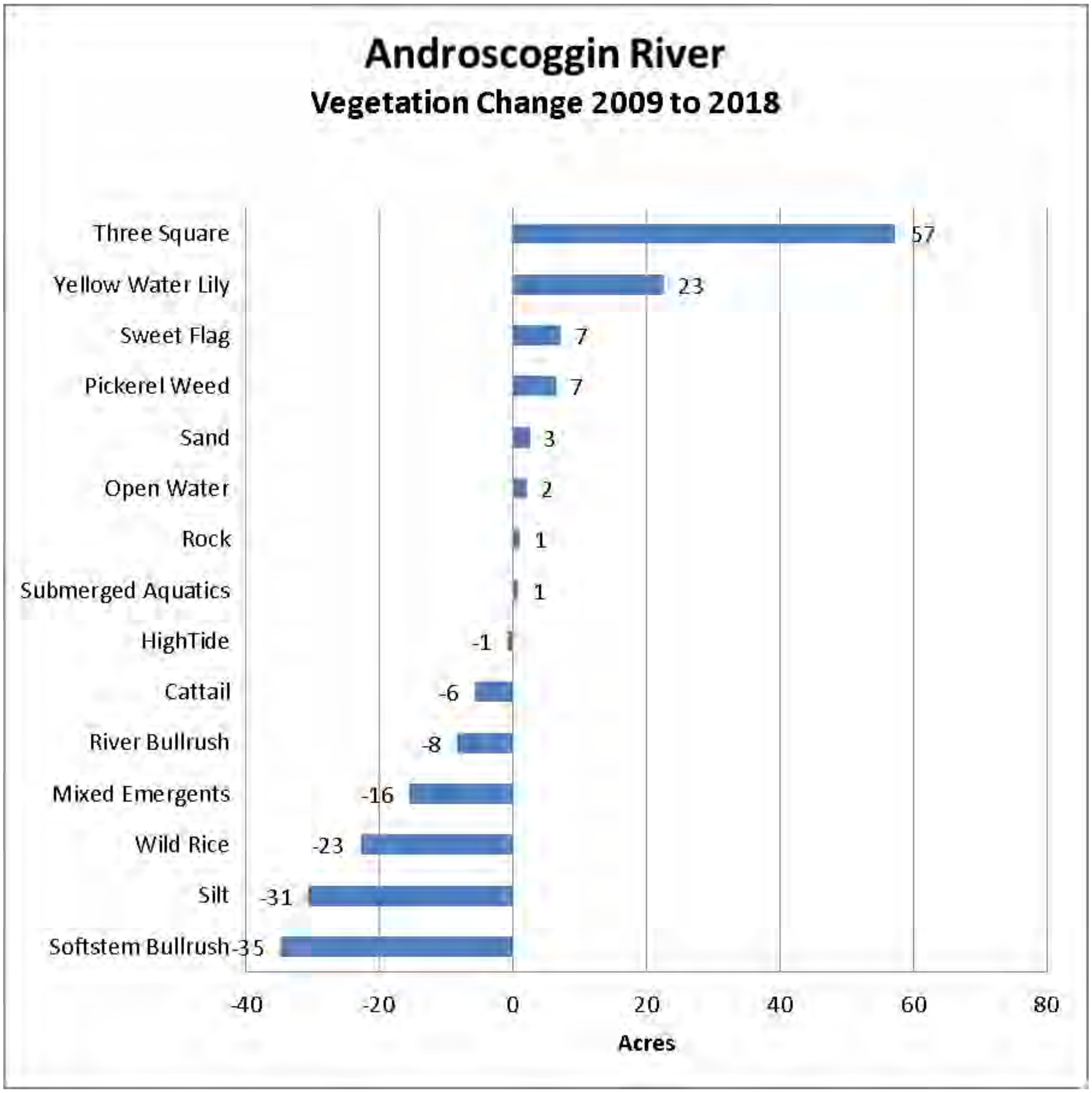
Muddy / Cathance

Wild rice showed the largest increase (90 acres) followed by submerged aquatics (36 acres) and yellow water lily (26 acres). Mixed emergent vegetation decreased the most (-131 acres), as did softstem bullrush(-27 acres), and pickerel weed (-24 acres). The total decrease in emergent vegetation in this section was 53 acres.



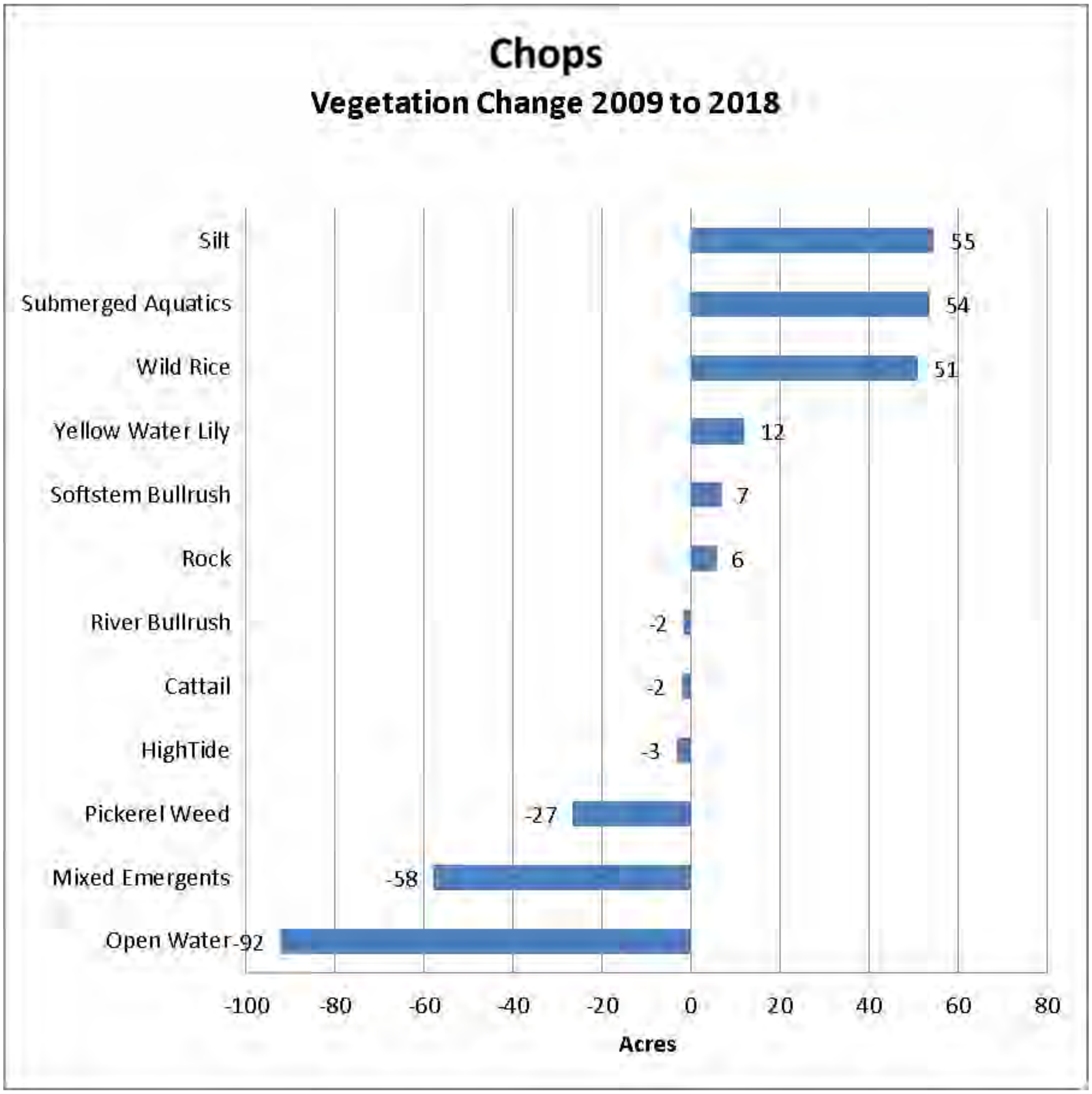
Androscoggin River

Three square showed the largest increase (57 acres) followed by yellow water lily (23 acres), sweet flag (7 acres) and pickerel weed (7acres). Softstem bulrush decreased the most (-35 acres) followed by wild rice (-23 acres), mixed emergents (-16 acres) and river bulrush (-8 acres). The total increase in emergent vegetation in this section was 6 acres.



Chops

This section showed a large increase in silt (55 acres), submerged aquatics (54 acres) and wild rice (51 acres). Yellow water lily and softstem bulrush increased slightly (12 acres and 7 acres respectively). Mixed emergent showed the largest decrease (-58 acres) followed by pickerel weed (-27 acres). The net decrease in total emergent vegetation in this section was 19 acres.



Buildings

Table 4.5 tallies the digitized buildings for the 2018 study area by section. The values shown in the table include buildings that can be seen on the orthophotos as well as buildings (those classed as IN_2018 = Maybe) that are considered to be probably present based on other evidence such as roads or docks, but are not visible on the 2018 orthophotos due to the location being overtopped by trees (see footnote 2). The number of buildings increased by only 87 over the whole study area, from 2009 to 2018 (1.5%). This is a net change that includes removal of 306 buildings and is a significant slowdown from the prior period which had a net increase of 1713 buildings. This slowdown can be attributed to the great recession and its lingering effects on new development.

Table 4.5. Summary of Building Changes between 2009 and 2018 by Section.

SECTION	Present in 2009	New Since 2009	Removed Since 2009	Net Change	2018 Total
Abagadasset R.	173	31	3	28	201
Androscoggin R.	3255	152	164	-12	3243
Chops	600	34	29	5	605
Eastern River	483	46	36	10	493
Middle Bay	47	2	0	2	49
Muddy/Cathance	716	62	29	33	749
Swan Island	961	66	45	21	982
Grand Total	**6235**	**393**	**306**	**87**	**6322**

5. SUMMARY

A Geographic Information System was used to replicate the 1998 study of Merrymeeting Bay (Sewall Company, 2000; Friedman, 2000) and later update in 2009 (Sewall company, 2010). In addition to the update of the land use and vegetation data summaries, a new spatial data base was created, along with an integrated GIS framework encompassing all five years of the study. Upland areas for a half-mile buffer surrounding the Bay were included. The methods used allow detailed cross-tabulation of conditions between years, showing acreage differences in land use and vegetation and where those changes occurred. Digital information resulting from this study will provide a good base for a more-detailed further review as well as future analyses, as long-term trends in the Bay continue to be examined. The 2018 orthophoto base will provide ready access to 2018 conditions, a ready source of additional characteristics not captured in the classification scheme, and a sound foundation for future studies.

6. REFERENCES

Anderson, J. R., Hardy, E. E., Roach, J. T. and Witmer, R. E., 1976, A Land Use and Land Cover Classification System for Use with Remote Sensor Data, U.S. Geological Survey, Professional Paper 964, p 28, Reston, VA.

Anderson, K. H., 1982. Summary of Results:1981 Vegetation Survey, Merrymeeting Bay. Unpub. interdepartmental memorandum, Maine Dept. Inland Fisheries and Wildlife, Augusta, Maine

Cowardin, Lewis M., Carter, Virginia, Golet, Francis C., and LaRoe, Edward T., 1979. Classification of Wetlands and Deepwater Habitats of the United States, U.S. Dept. of the Interior, Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Friedman, Ed, 2000. Final Report: Maine Outdoor Heritage Fund (MOHF) Project: Aquatic and Upland Habitat Assessment of Merrymeeting Bay. Friends of Merrymeeting Bay, P. O. Box 233, Richmond, ME.

Lichter, John, Heather Caron, Timothy S. Pasakarnis, Sarah L. Rodgers, Thomas S. Squiers, Jr, and Charles S. Todd, 2006. The Ecological Collapse and Partial Recovery of a Freshwater Tidal Ecosystem. Northeastern Naturalist, 13(2):153-178.

Olson, David P., 1958. The use of aerial photographs in studies of marsh vegetation. M. S. Thesis, University of Maine, Orono, Maine

Sewall, J. W. and Co., 2000. Aquatic and upland habitat assessment of Merrymeeting Bay. Assessment report prepared for Friends of Merrymeeting Bay, Old Town, ME.

Spencer, Howard E. Jr., 1966. Merrymeeting Bay Investigations. Unpub. Manuscript. Job Completion Report Job A-4, P.R. Proj. W-37-R-14. Maine Dept. Inland Fisheries and Wildlife, Augusta, Maine

APPENDIX A: VEGETATION AND LAND USE DATA DESCRIPTION

ALPHA18 - Unique photo-interpreted code from which other codes (except WETL_SYS) were derived. For example, the code "WR" was used by the photo-interpreter to mean wild rice (in 1998 and for previous years, we used the letters A-H for vegetation codes, following the original work by Spencer) – see the ALPHA codes below under the VEG09 code list. The ALPHA value was recoded to WET for land use, EM for land use subclass, and EM1 for WETL_CLS. Similar re-coding was done for other values of ALPHA. ALPHA itself was never changed from the original interpreted value unless changed by the interpreter.

LUCLASS18 Land use class 3-character alphabetic

AGR	Agricultural (cropland or pasture in current or recent use)
COM	Commercial (business or commercial predominant use)
FOR	Upland Forest (predominant land use forest)
IND	Industrial (manufacturing facilities and associated land)
OW	Open Water (lake, river, or bay areas under water greater than a few inches deep at the time of photography)
RES	Residential (homes and related neighborhoods)
UHE	Upland Herbaceous (large expanses of lawn not obviously associated with residence)
USS	Upland Scrub-Shrub (usually abandoned agricultural field)
WET	Wetland (general class for upland and bay wetlands other than open water)

LUSUB18 - Land use subclass. 4-character alphabetic. Some of the land use classes were broken into subclasses. For those that were not broken down a synonym code was used in the subclass attribute. This allows the land use subclass attribute to be used as an exhaustive alternative breakdown of land use. The subclass codes, by class code are as follows:

AGR always subcoded AGR

COM

COM	developed commercial area, typically mostly buildings, paved or non-vegetated
YD	harvest yarding area in forest
GP	gravel pit
TL	primary use transmission line

FOR

SW	softwood
MI	mixed softwood and hardwood
HW	hardwood

WET no subclass breakdown for uplands in 1956, 1981

AB	aquatic bed
EM	emergent vegetation
PFO	forested wetland
HT	high tide zone – unvegetated areas above high tide
ROCK	rock showing within the bay or bay area

SAND	sand flats (may be submerged)
SILT	silt (may be submerged)
USS	palustrine scrub-shrub wetland

IND always subcoded IND

OW always subcoded OW

RES always subcoded RES

USS always subcoded USS

UHE always subcoded UHE

VEG18 and VEG_DESC18 - Vegetation code. 1-character alphabetic code for emergent vegetation type and 20-character description with code – this code is consistent with the vegetation codes used in earlier studies. Codes are as follows:

A	wild rice (ALPHA = 'WR')
B	yellow water lily (ALPHA = 'YL')
C	sweet flag (ALPHA = 'SF')
D	softstem bullrush (ALPHA = 'SB')
E	river bullrush (ALPHA = 'RB')
F	pickerelweed (ALPHA = 'PW')
G	mixed emergents (ALPHA = 'ME')
H	cattail (broad-leaved or narrow-leaved) (ALPHA = 'CT')
I	three square (common three square) (ALPHA = 'TS'

FORCOV18 Forest cover types are made up of three components, species composition, size class, and crown closure. The four-character code is made up of the following codes for each of these components:

FORSPP18 (species composition)

H	Greater than 75% Hardwood
S	Greater than 75% Softwood
HS	Hardwood-dominated mixture of hardwoods and softwoods (hardwood 50-75%)
SH	Softwood-dominated mixture of hardwoods and softwoods (softwood 50-75%)

FORSIZ18 (a size classification roughly indicative of mean stand height)

1	10' tall
2	~10-30' tall
3	~30-50' tall
4	~>50' tall

FORDEN18 (canopy closure)

A	71-100%
B	41-70%
C	11-40%
D	0-10%

ESTUARY18 – “YES” if polygon is part of the area considered to be estuary in the particular year, otherwise “NO”.

APPENDIX B: DATA AND MAPS PROVIDED SEPARATELY

MAPS

Two hardcopy wall maps showing the five study years side by side, with land use, vegetation, buildings and roads of each of the five years:

- 1:40,000 scale covering all sections;
- 1:10,000 scale covering the central part of the study area (centered on Abagadassett R. and Middle Bay section).
- 1:15,840 (1 inch = 1 quarter mile) scale vegetation types with orthophoto background.

Digital versions of the above maps in (Maps folder on flashdrive .pdf and .jpegformat).

Digital version of the flight line map for aerial photographs that is provided in Appendix C of report (Maps\flight_lines folder).

Digital version of close-up comparison areas that are provided in Appendix D of report (Maps\close-ups folder).

REPORTS

Three printed copies of this report.

Digital version of this report in Microsoft Word and Adobe .pdf format (Report folder on flashdrive)

GIS DATA

ArcGIS map project files (.mxd's) set up for viewing in ArcGIS 10.4 with the delivered data (GIS\mxd folder):

- Wall map 1:40,000 (deliv_wide.mxd);
- Wall map 1:10,000 (deliv_wide_MiddleBay_enlargement.mxd); showing the 2018 polygons, buildings, and roads with the orthophoto background (vegetation_types_with_ortho_background.mxd);
- Layer files for symbolizing the various map layers.

ArcGIS v 10.4 File geodatabase FOMB_2018_data.gdb in UTM Zone 19 Meters, Datum NAD83 containing the following feature data sets (\GIS folder):

- Vegetation_LandUse – polygon feature classes for each year, attributed as described in appendix A.
- Veg_Analysis_2018 – polygon feature class:

Union_18_09_98_81_56_Section_Town – polygons resulting from the union of four years of vegetation and land use polygons with the above section and town polygons.

- Veg_Analysis_2009 – two analysis feature classes:
  Intersection_Sections_StudyArea_Town – polygons attributed with section and town and outlined by the outer extent of the study area;
  Union_09_98_81_56_Section_Town – polygons resulting from the union of four years of vegetation and land use polygons with the above section and town polygons.
- Roads – line feature classes for roads in each year;
- Buildings – point feature classes for buildings in each year;
- Base_2018 – additional data from the public domain describing base features in and around the study area, including water features from the Maine Office of GIS (Coast, Rivers, Streams), National Wetlands Inventory polygons (MMB_NWI), Towns (MMB_Towns), and Otrans (railroads or abandoned railroads and utility lines – the railroad centerlines were adjusted to fit the orthophotos, but the transmission lines were not;
- Two point feature classes: the photo-centers (photo_centers_18) and the reference points (mmb2018_ground_truth_points) with associated attributes.
- Raster mosaic USGS_topo – mosaic of USGS maps covering the study area and used as a background in the wall map (GIS\pgdb folder on DVD 2).

Shapefiles and kml files of the above roads, building, and vegetation data sets in UTM Zone 19 Meters, Datum NAD83 containing the veg/land use, road, and building feature data sets (GIS\shapes and GIS\kml folder).

ArcGIS v 10.4 file geodatabase FOMB_2018_imagery.gdb containing the following:

- Raster data catalog MMB09 – mosaicked 2018 CIR orthophotos (when delivered to local drive, will need to be linked to .mxd's, or copied with ArcCatalog into file geodatabase FOMB_2018_imagery.gdb under folder GIS\imagery);

FGDC metadata in .html format for the feature classes generated for this study is contained in the folder \GIS\metadata.

ANALYSIS DATA

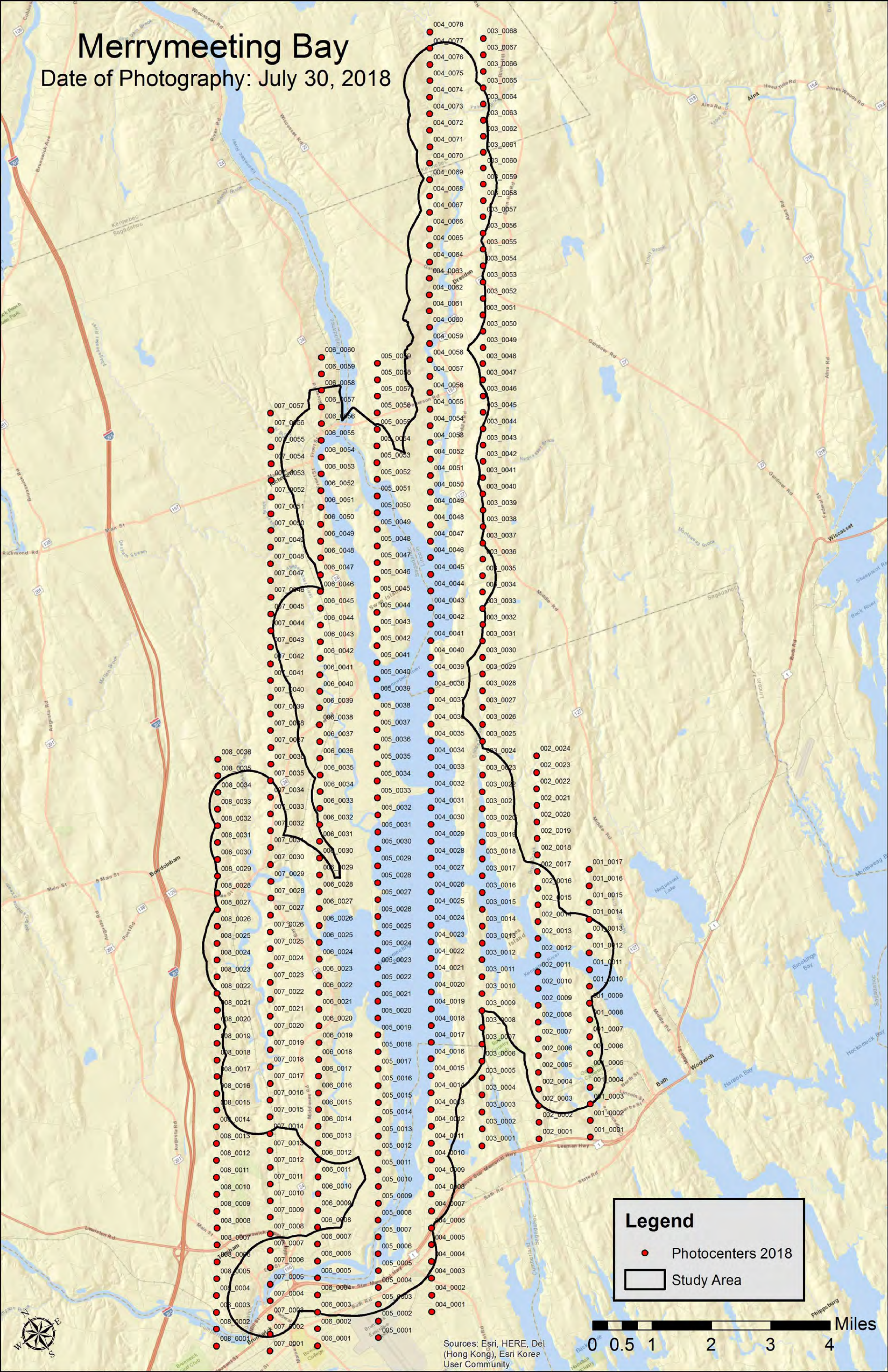
Excel spreadsheets used in the analysis (Analysis folder flash drive):

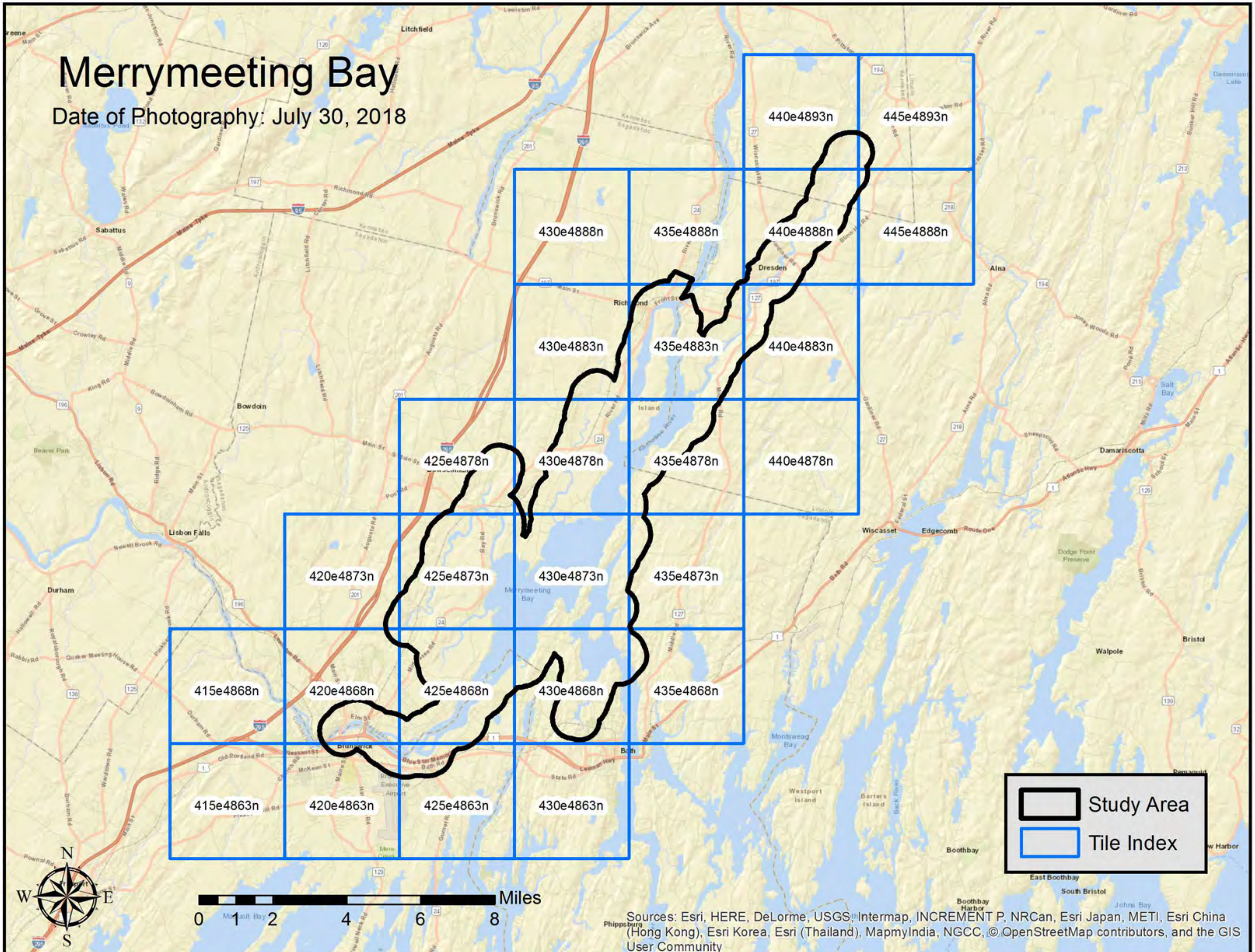
- Union_18_09_98_81_56_Section_Town_v5work.xls – contains the raw data from the union data set, pivot tables, and the tables and charts presented in this report;
- MMB_18_Bldgs_withtables.xls – 2018 buildings by section.

RAW DIGITAL IMAGERY

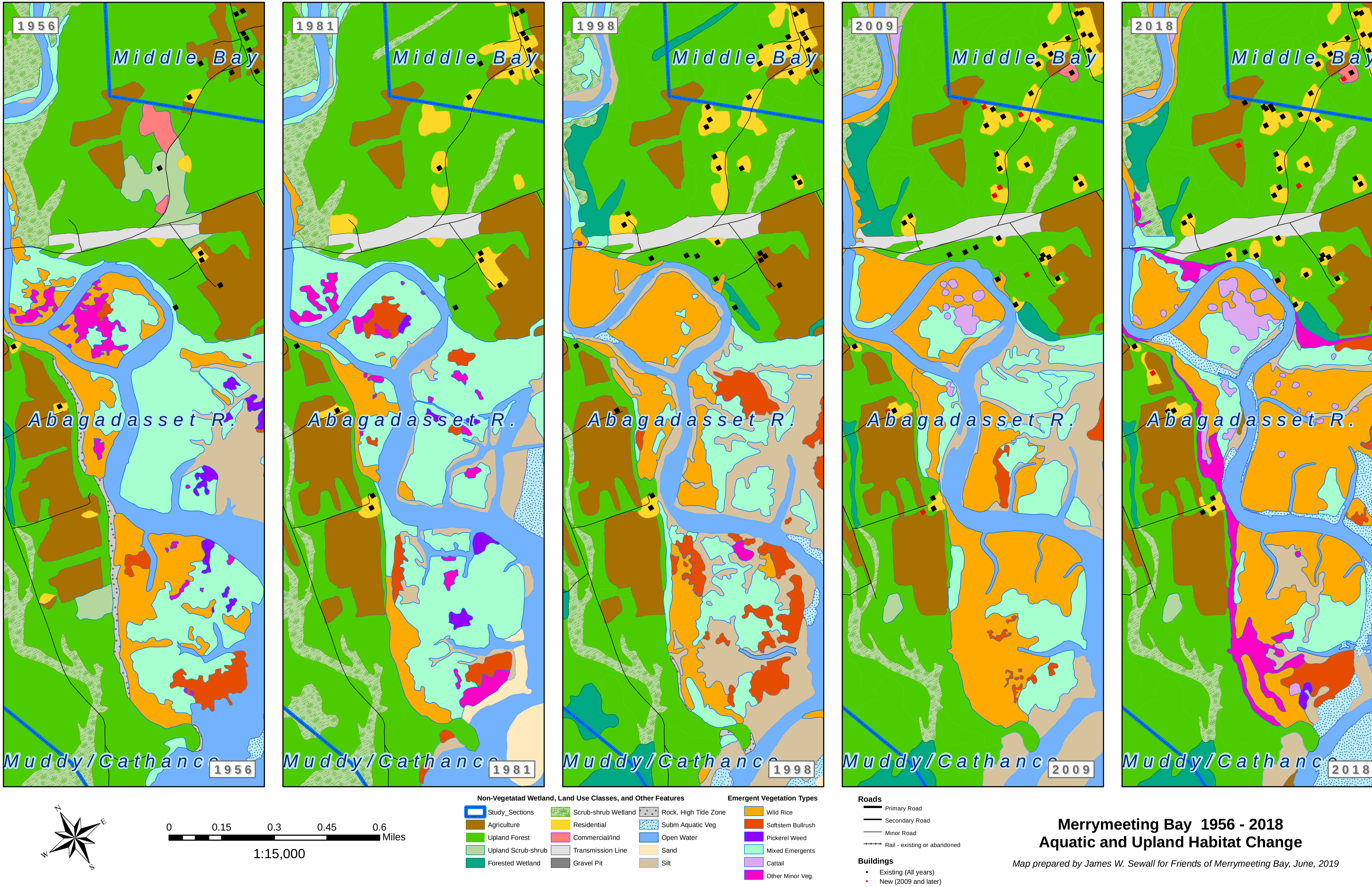
Raw digital scans of aerial imagery (GSD approximately 20 cm) in TIF format along with supporting data (\imagery\raw).

APPENDIX C: FLIGHT LINE AND PHOTO INDEX


Merrymeeting Bay
Date of Photography: July 30, 2018
Legend
Photocenters 2018
Study Area
Miles
0 0.5 1 2 3 4
Sources: Esri, HERE, Del
(Hong Kong), Esri Korea
User Community

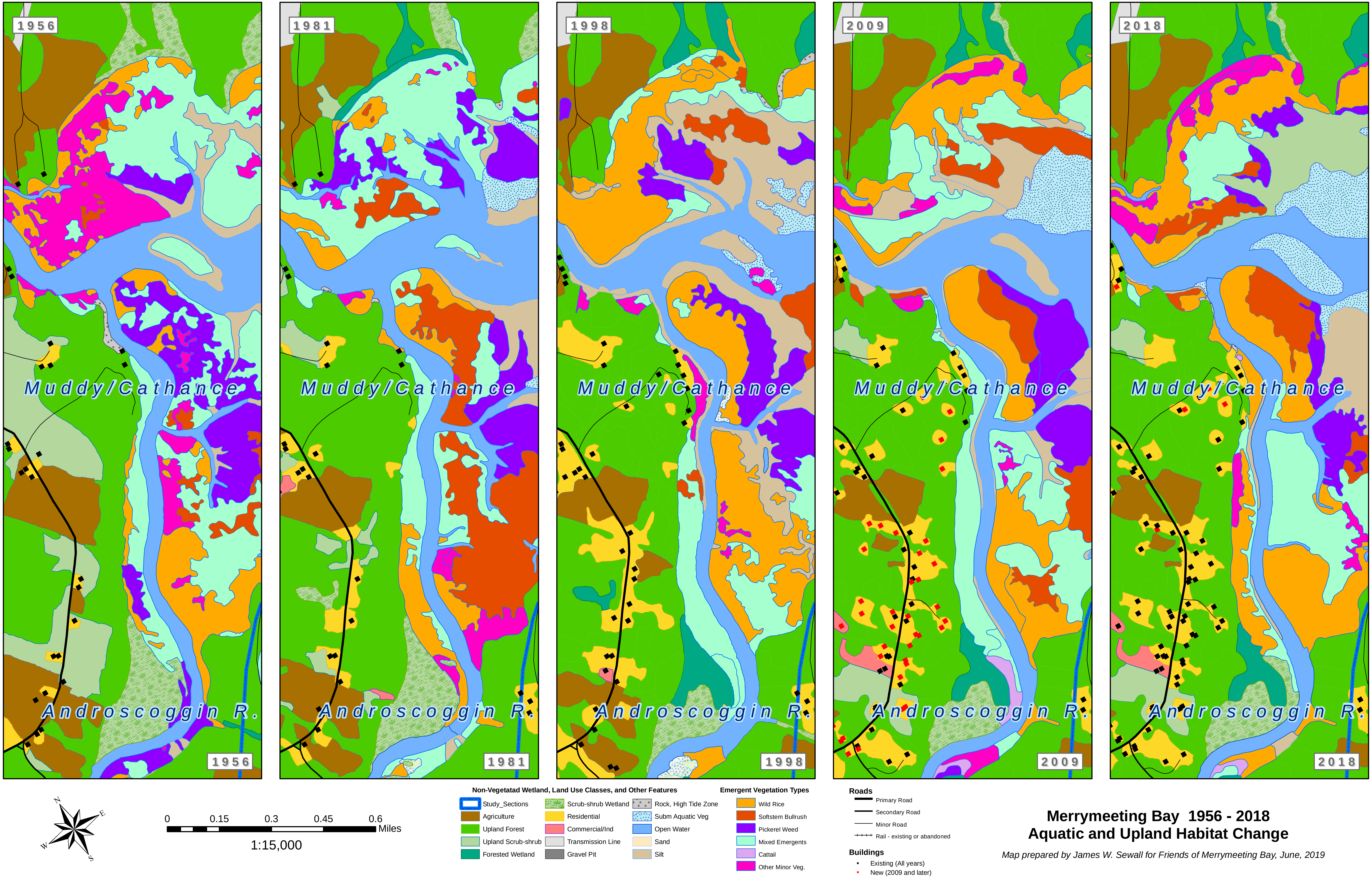

Merrymeeting Bay
Date of Photography: July 30, 2018
440e4893n
445e4893n
430e4888n
435e4888n
440e4888n
445e4888n
430e4883n
435e4883n
440e4883n
425e4878n
430e4878n
435e4878n
440e4878n
420e4873n
425e4873n
430e4873n
435e4873n
415e4868n
420e4868n
425e4868n
430e4868n
435e4868n
415e4863n
420e4863n
425e4863n
430e4863n
Study Area
Tile Index
N
W
E
S
0 1 2 4 6 8 Miles
Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

APPENDIX D: MAPS SHOWING LAND USE AND VEGETATION CHANGE FOR SELECTED AREAS



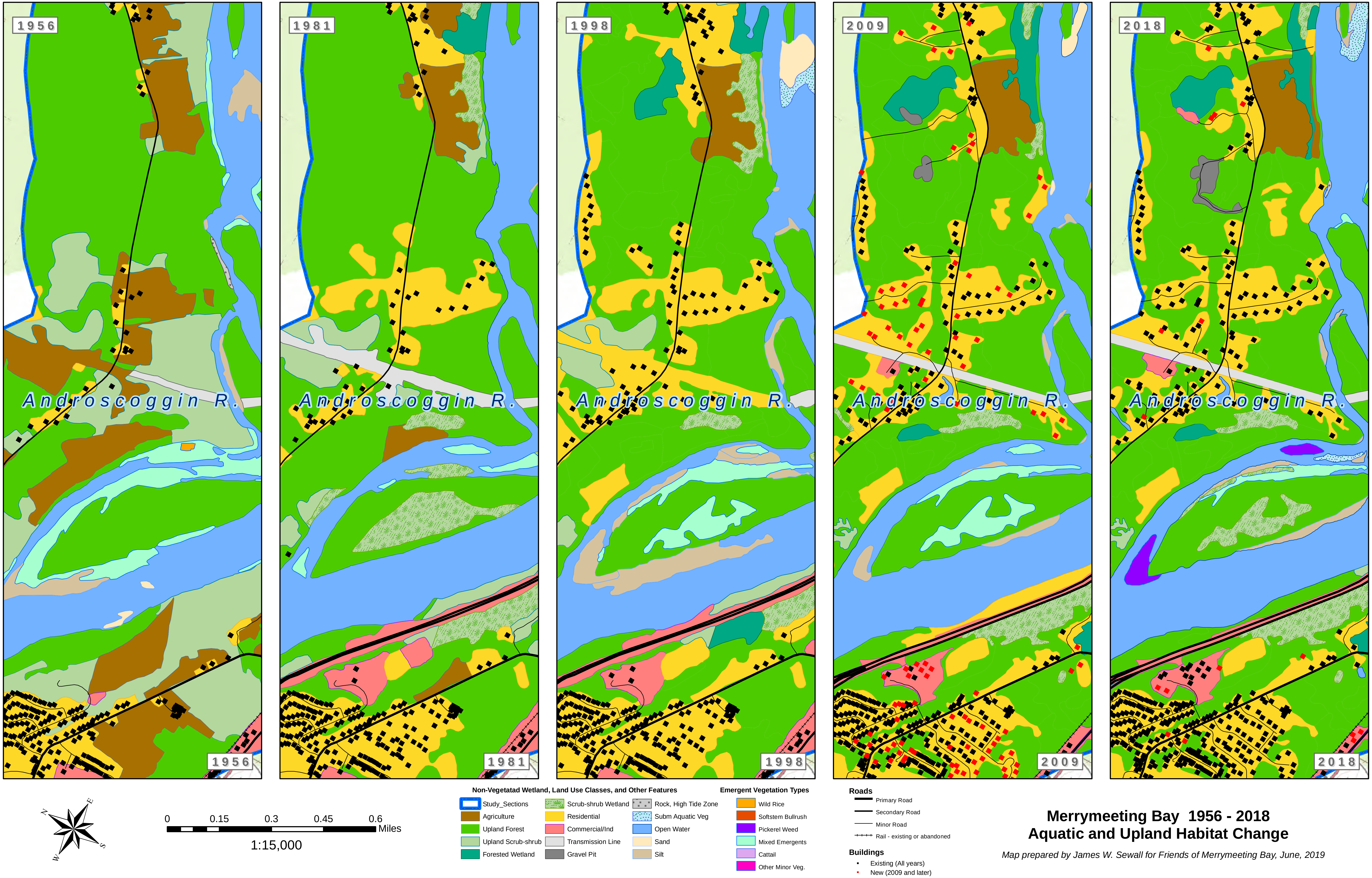
Merrymeeting Bay 1956 - 2018
Aquatic and Upland Habitat Change

Map prepared by James W. Sewall for Friends of Merrymeeting Bay, June, 2019



Merrymeeting Bay 1956 - 2018
Aquatic and Upland Habitat Change

Map prepared by James W. Sewall for Friends of Merrymeeting Bay, June, 2019



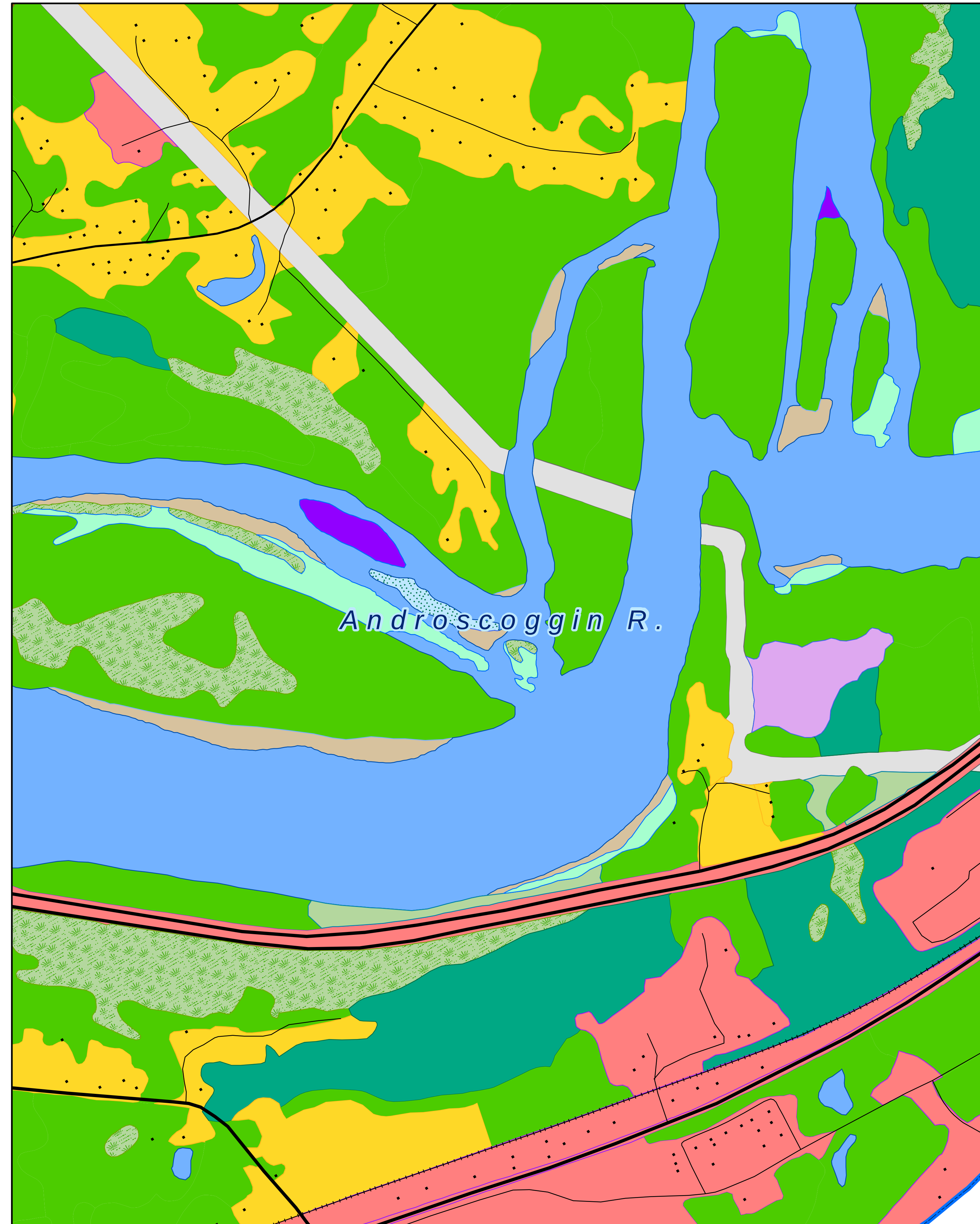
Merrymeeting Bay 1956 - 2018
Aquatic and Upland Habitat Change

Map prepared by James W. Sewall for Friends of Merrymeeting Bay, June, 2019

APPENDIX E: COMPARING ORTHO PHOTOGRAPHY AND MAPPING


Abagadasset R.


Muddy/Cathance
Androscoggin R.


Androscoggin R.