

Final Report

GIS Mapping for Mendenhall Wetland State Game Refuge

Vegetation types, tidal elevations, property boundaries, and their relation to
glacial rebound and the conservation of accreted land.

by **Discovery Southeast**
for the Southeast Alaska Land Trust
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SEALTrust

The Southeast Alaska Land Trust cooperates with communities and landowners to ensure that vital natural areas remain in place for the well being of each generation.

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Discovery Southeast

Founded in 1989 in Juneau and serving communities throughout Southeast Alaska, Discovery Southeast is a nonprofit organization that promotes direct, hands-on learning from nature through natural science and outdoor education programs for youth and adults, students and teachers. Discovery Southeast naturalists aim to deepen the bonds between people and nature.

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SEAWEAD

Southeast Alaska Wilderness Exploration, Analysis & Discovery (SEAWEAD) is comprised of a small group of naturalists and educators. SEAWEAD's mission is to facilitate research-based cooperative stewardship of wild lands in Southeast Alaska.

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The Mendenhall Wetlands complex has the second greatest acreage of vegetated tidal salt marsh of all estuaries in Southeast Alaska (exceeded only by the Stikine River marshes). It ranks 7th in extent of unvegetated tidal flats. It is widely acknowledged to be one of the key migratory waterbird stopover locations of coastal Alaska. Recreational value is very high, and will continue to grow.

Estuaries are among the world's most dynamic habitats, and nowhere is this more true than in northern Southeast Alaska. As land here rises from glacial rebound, tidal salt marshes change dramatically. Vegetation communities migrate perceptibly seaward from decade to decade. And where property boundaries are based upon tidal elevation, land may also change ownership.

The Southeast Alaska Land Trust (SEALTrust) has embarked upon a project entitled *Conserving accreted land adjoining the Mendenhall State Game Refuge*. The project goal is to identify challenges and opportunities in conservation of this critically important estuary complex. SEALTrust subcontracted with Discovery Southeast (DSE) and Southeast Alaska Wilderness Exploration, Analysis and Discovery (SEAWEAD) to provide

maps and GIS* analysis of the Refuge, to be used in the conservation assessment. SEALTrust's primary focus is on the belt of private properties along the refuge boundary.

In addition to compiling air photography and GIS coverages from several sources, Discovery Southeast naturalists conducted field surveys in late summer, 2003, to gather data for a complete vegetation map of the refuge. An understanding of refuge vegetation, the wildlife it supports, and changes to vegetation over time, is a first step in setting conservation priorities. We hope that this report and the accompanying GIS project will be useful not only to SEALTrust, but to ADF&G refuge managers, other regulatory agencies, advisory groups, consultants, researchers, and recreational users of the Mendenhall Wetland State Game Refuge.

Recent advances in ArcMap allow us to share the GIS project electronically, even with those lacking access to the full ArcMap program. A read-only "ArcReader" document containing all of the essential components of the refuge project is available on CD, along with the applica-

Fig 1 View south over Gastineau Channel to Johnson Creek estuary on Douglas Island, April 29, 2002. Photo taken about an hour after tide peaked at 16.5 feet. Arrows show darker, recently wetted border along the channel where this tide had reached.

Small spruces in "uplift meadow" in left distance are colonizing former tideland. Most of the vegetation between Johnson Creek and Gastineau Channel is grass-dominated high marsh, extending from extreme high water out to about the 16.5 foot elevation.



*GIS stands for Geographic Information Systems - computerized mapping and spatial analysis. The most widely used GIS application is ArcMap. Until recently this expensive suite of programs was only available to specially-trained professionals. But the advent of the free program ArcReader makes it possible to prepare maps, overlays and data sets that anyone can examine on a home computer. Similar in concept to .pdf files created for Adobe Acrobat, ArcReader .pmf documents allow users with no GIS experience to turn map layers on and off, zoom in and out, measure distances, query data layers, and print anything viewable on screen.

tion itself. Those not trained in GIS will find ArcReader intuitive and useful. Others with access to ArcMap (or earlier versions of ArcView version 3) will of course prefer the full refuge project.

Previous work

Many related investigations have been conducted throughout the Mendenhall Refuge, and some are especially valuable for their historical context.

John Crow, currently at Rutgers University, installed permanent vegetation plots on the Mendenhall Wetlands in the 1960s. In 2001, he returned to Juneau on contract with the Alaska Dept of Fish and Game for repeat measurements on these plots.

Sarah Watson did graduate studies of birds and habitats of the Mendenhall Wetlands in the mid 1970s, and produced a large scale vegetation map. (Watson, 1979)

Cathy Stone conducted doctoral studies of coastal marsh vegetation on the Mendenhall and Eagle River wetlands, also in the mid-1970s. Her delineation of community types has proven useful in subsequent mapping efforts on the wetlands by SWCA, described below. (Stone, 1993)

Paul Adamus came to Juneau in the mid 1980s to conduct wetland assessments for the CBJ. A particular strength of the Adamus protocol was the integration of bird surveys with vegetational descriptions. Focus was primarily on freshwater wetlands, but as part of the field crew I conducted combined bird/vegetational surveys on the upper margins of the refuge, and at uplifted former tidelands at Brotherhood Park. (Adamus 1987)

Ed Cain, Jack Hodges, and Everett Robinson-Wilson surveyed birds on the wetlands for the US Fish and Wildlife Service throughout 1986. Their report (Cain *et al.*

1987) provided a baseline for our subsequent bird “hotspot” study, described below.

Dan Bishop (Environaid), Bob Armstrong and I studied the area around Temsco and the east end of the runway in 1986 on contract with Isbul Associates, who prepared the EIS for an extension of the taxiway. We created detailed vegetation maps for parts of the wetlands that have since been filled or altered by barriers to tidal flow. (Bishop *et al.* 1987)

R&M Engineers studied potential realignment of lower Duck Creek in the mid 1990s. For that study I prepared a detailed vegetation map of “Duck Creek Triangle” and a short environmental report (Carstensen, 1995).

SWCA Inc. has completed fine-scale habitat mapping for the Juneau International Airport property, and more coarse-scale mapping based largely on photo-interpretation for the greater refuge. Their final EIS has not been published at time of this report, but maps can be downloaded from their website at www.jnu-eis.org.

Bob Armstrong, Mary Willson and I conducted a yearlong study of bird “hotspots” on the Mendenhall Refuge on contract with the USFWS, beginning in spring 2002. (Armstrong *et al.* 2004). The full study was published through the Juneau Audubon Society and Taku Conservation Society. We feel that this is the most complete synthesis of Mendenhall Wetlands natural history. Chapter 4 of that report – *Glacial rebound, vegetation and birds* – describes vegetational types on the refuge. Copies have been provided to SEALTrust and others concerned with management issues on the refuge. Rather than repeating the information and illustrations in Chapter 4 for the current SEALTrust summary, the reader is referred to the “hotspots” report. Copies are available on CD, and will also

be available on the Juneau Audubon website for downloading. (www.juneau-audubon-society.org)

Methods

The base imagery for our project is 9-inch-pixel color infrared (CIR) digital orthophotography commissioned in August 2001 by the airport EIS consultants, SWCA Inc, along with the City and

Fig 2 August 2001 color infrared photo. Runway on left, Lemon Creek at center right. Dots show downloaded GPS waypoints – each color from a different day’s visit. (“Waypoints” are positions determined by satellite triangulation using a Global Positioning Systems unit, or GPS.)

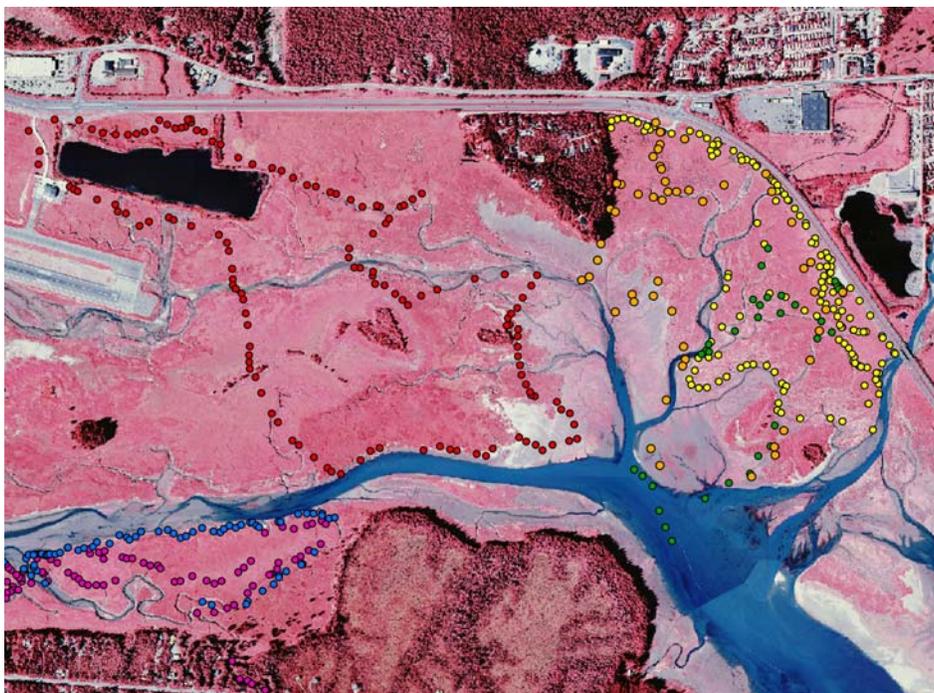
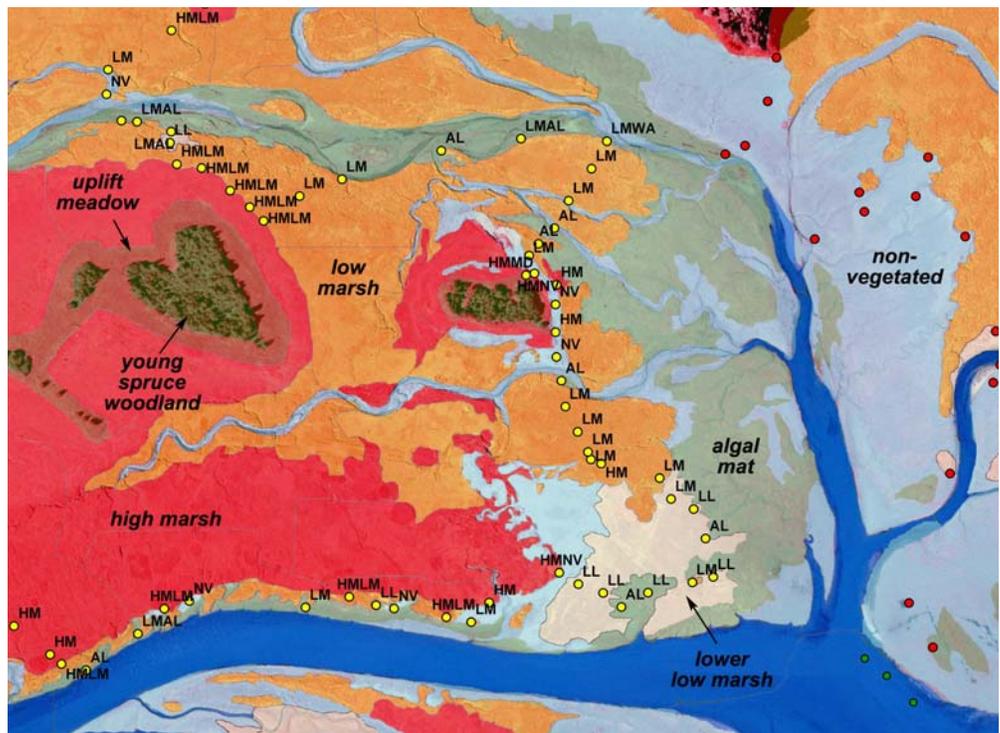


Fig 3 Also from Aug 2001 CIRs. This sample from our vegetation layer shows spoil islands (from dredging of Gastineau Channel) in center of Fig 2. Waypoints are labeled with community type. HM = high marsh. LM = low marsh. LL = lower low marsh (also called succulent marsh). AL = algal mat community. NV = nonvegetated. WA = water. Combined types, eg. HMLM, show community boundaries.



Borough of Juneau. Bruce Simonsen, GIS manager for CBJ, provided us with these images, and subsequently, additional data layers. All images and covers are in NAD 83, Alaska state plane, zone 1 (US survey feet).

The Mendenhall Refuge requires 50 of these very high resolution 3700-foot-square tiles. At high magnifications, this photography shows details such as the root wads of drift logs. Color infrared reveals some differences in vegetation communities that are not visible in true color photography. However, one of the key community boundaries on the refuge, between high marsh and low marsh (see Armstrong *et al.*, 2004, p. 10-16), was not readily apparent from either color or texture on the SWCA photos. To map vegetation on the tidal marsh, we clearly needed ground surveys.

Current vegetation. In early September, 2003, I made 7 visits to the refuge to collect plant community data, sometimes with the help of Discovery naturalist Terry Schwartz. We took GPS waypoints that were later downloaded onto the CIR imagery. At each point we recorded plant community, dominant species, and additional comments on substrate, successional

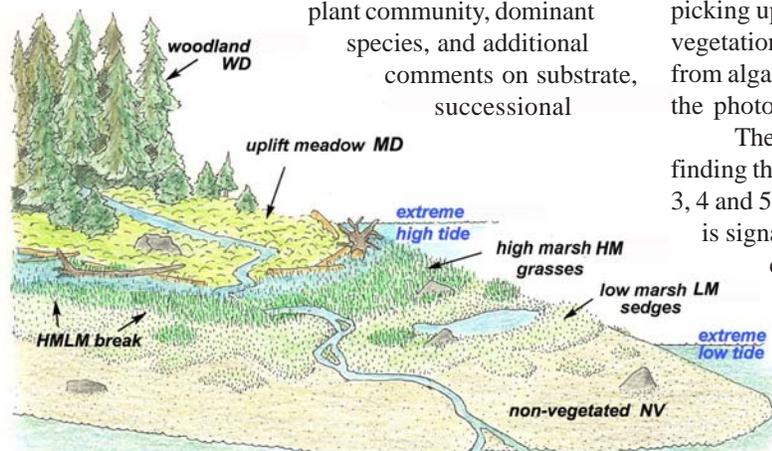


Fig 4 Salt marsh zonation

trends, wildlife sign, etc. The notes were taken on tape recorder in order to cover as much ground as possible. Special effort was made to collect waypoints on borders between community types. At times, we would follow these community breaks, recording strings of waypoints.

Figure 2 shows examples of the waypoints. Field notes were transcribed from tape recorder directly into the waypoint database in GIS, so that the waypoint position could be viewed on the monitor while entering data, allowing correlations between photo and ground-based observations to emerge. Next, waypoints were labelled with community type (Fig 3), and polygons were drawn representing the key salt marsh vegetation types. Although the photography used in delineation was taken in August, 2001, the vegetation layer in our ArcMap project is called veg2003, because it reflects the more recently acquired ground data.

The color infrared images are particularly good for picking up the lower contact of vascular and algal mat vegetation with bare sediments. Distinguishing vascular from algal communities, however, was not always easy on the photos.

The most challenging part of the mapping was finding the high marsh/low marsh break (HMLM on Figure 3, 4 and 5). In some parts of the 2001 imagery this boundary is signalled by a subtle color shift. However, these colors vary from one part of the refuge to the other. In some areas high marsh may be paler than low marsh, and in other areas it may be darker.

Fortunately, we acquired an additional resource in this high marsh/low marsh delineation. During the Hotspots study (Armstrong *et*

Fig 5 October 10, 2002. True-color digital photo taken on flight with Jack Hodges, USFWS. Egan Drive crosses Lemon Creek at center. At this time, the sedges of the low marsh had wilted, while grass blades remained erect and retained some of their green color.



al., 2004), we were initially limited by the lack of low-tide aerial photography for mapping of the critically important mussel/barnacle/rockweed communities. On October 10, 2002, I flew over the refuge with Jack Hodges of USFWS to take vertical air photos. The 20-minute flight was centered around a zero tide. Photo coverage of the refuge was not continuous, but I captured most of the key areas of mussel/barnacle/rockweed beds, and enough of the zero-foot waterline to create an approximate contour

for that elevation. The great unanticipated benefit of the October photography, however, was the clear distinction between grasses of the high marsh and sedges of the low marsh (Fig 5).

Vegetation types mapped on the Mendenhall Wetlands

This classification matches that of SWCA for the Airport EIS project. I have used roughly similar color codes for easy comparison. Both systems are based on Stone(1993) for salt marsh (tidal) communities. In the lower tidal reaches I have added 3 community types (LL, AL, MS) important to fish and birds. See Armstrong et al. (2004) for discussion of ecology and succession. The full refuge coverage of the veg2003 layer is shown in Appendix C

supratidal communities

WD wooded – Young stands of spruce, alder, willow or cottonwood on former tideland. (Older mature conifer on refuge border is not delineated). Where colonizing trees are dispersed, they are not individually mapped, but included with MD.

MD meadow – Diverse forb or graminoid meadow on raised former salt marsh. Includes fireweed, cow parsnip, lupine, etc.

SD seeded or mowed - human-altered communities such as runway margin, highway median, golf fairway, etc.

tidal communities

HM, LM and NV form nearly continuous elevational belts. LL, AL and MS are patchier in distribution.

HM high marsh – Grass-dominated upper portions of the salt marsh. Typically from Extreme High Water Spring (EHWS) down to about the 16 or 17-foot tide level. Includes rye grass,* hair grass and foxtail barley. With glacial rebound this type is displacing the low marsh .

LM low marsh – Lyngbye sedge-dominated lower portions of the salt marsh. Flooded almost daily. Extremely important to grazing waterfowl and mammals, as well as to invertebrate

communities supporting rearing salmonids and other marine fish.

LL lower low (or succulent) marsh – Dominant species such as goosetongue, sea milkwort and arrow-grass (not a true grass, as indicated by the hyphen) are shorter in stature and less fibrous than grasses or even sedges. Many are eaten by grazers. An exception to the general succulence of the LL community is alkali grass, more tolerant of salinity than the taller high marsh grasses.

AL algal mat – Carpet-like, interwoven filaments of algae including Vaucheria sp.

MS mussel/barnacle/rockweed – Variable dominance. Needs coarse material in the sediment mix for anchorage. Because this type is only briefly exposed, and we have only partial refuge coverage of low-tide photography, my map may have missed some patches of this very important type.

NV non-vegetated – mostly bare sediments, fine to coarse.

WA water – mapped from the mid-stage of tide shown on the 2001 CIR photography. Level of course changes hourly.

* Common names for selected tidal marsh plants follow Pojar and MacKinnon, 1994). For scientific names, see Appendix A)

Lynghby sedge superficially resembles a grass, even at close quarters. Sedges are generally more palatable than grasses to grazers, however, because they are less fibrous. Throughout most of the growing season this difference is not visually apparent. But during fall senescence, Lynghby sedges quickly wilt and lie prostrate, while high-marsh grasses remain erect. The sedges lose their green color and fade to a pinkish tan. Grass colors also fade, but they hold their green coloration longer. It turned out that October 10th was an ideal time to photograph the HMLM break.

In ArcMap, I georeferenced 26 of the October 2002 true-color aeriels and arranged them sequentially over the accretion.mxd project. These images could be toggled on and off as I drew polygons for high marsh and low marsh communities. While my October shots do not cover the entire refuge, I feel confident that the HMLM break is generally accurate on the veg2003 layer. The October imagery also helped in some areas to separate algal mat communities (AL) from the vascular “lower low” marsh (LL).

On the veg2003 layer, as well as for historical and future projected veg layers, I have included two areas of salt marsh on private lands contiguous with the refuge:

- 1) golf course and other properties north to Crazy Horse Drive.
- 2) estuaries of Switzer, Lemon and Vanderbilt Creeks.

These wetlands, although privately owned, and in many cases altered or impaired, are functionally a part of the greater Mendenhall Wetlands, and are therefore included in the total acreages reported for wetland community types, past, present and future. By making them part of the assessment, we hope to offer a more comprehensive picture of historical and future change. They may also be considered as potential mitigation purchases, for eventual inclusion in the Mendenhall Refuge.

The ArcMap layer called veg2003 is a snapshot in time. By the end of this decade, it will be obsolete. Salt marsh communities respond closely to duration of tidal submergence and exposure, water currents, and sediment composition, and all of these physical features are changing with glacial rebound and with human alterations to marsh topography. Refuge management and conservation strategies depend on understanding of successional trajectories. Veg2003 should be only one layer in a “moving picture” of salt-marsh vegetation that includes past, present and future.

To create this moving picture, a key step in our refuge mapping plan was correlation of vegetation communities with tidal elevation. The CBJ has been developing LIDAR-generated contours for the refuge, but because of technical problems, these were not available at time of our project completion.

As an interim solution, Bruce Simonsen has given us a “provisional” 15.4-foot (mean high water) contour (Appendix B). In some places, “mean high water” defines the boundary between refuge and private lands. It is also helpful in understanding vegetational distribution. The current “15.4tideline” layer in our ArcMap project will be replaced eventually by a more extensive set of contours, and even the 15.4 line will no doubt be revised.

Our “15.4tideline” layer has no legal standing, will be revised, and is to be used strictly for initial discussions among SEALTrust and other groups considering wetland conservation issues.

Historical vegetation To create maps of vegetation communities in the past, we collected, scanned and georeferenced air photography from 1948, 1962, 1967, 1979 and 1984. Of these coverages, only 1962 and 1979 were acquired for the entire refuge. The earliest photography in my personal collection—the 1948 SEA series—extends west only to the mouth of Fish Creek, and is missing the mouth of Mendenhall River and Peninsula. Even earlier photography, from 1929, does exist for portions of the Mendenhall wetlands, but we were unable to locate copies. These earliest photo series—1929 and 1948—are useful for mapping obvious features like roads and streams, but both are coarse in resolution compared to subsequent photography, and would be inadequate for salt-marsh vegetation delineations.

The best of the older photography for vegetation mapping is the NASA 1979 CIR series. Although taken from very high elevation at a scale of only one inch to the mile, resolution is high enough to permit considerable enlargement. More importantly, only on this photography can grassy high marsh be distinguished from sedge low marsh. In this regard it is even better than the much higher resolution 2001 CIRs.

Tracing over the georeferenced 1979 CIRs, I created a shapefile showing extent of meadow, high marsh and low marsh (MD, HM and LM, respectively) for that period. Other marsh communities are much harder to map, and

would require ground-truthed information, as was true for the 2001 imagery. These three wetland types, however, are the most critical for an understanding of

Table 1 Historical photography for Mendenhall Wetlands

year	agency	scale	type	georef.	% refuge covered	% acquired	resolution
1929	Navy	1:20,000	B&W	no	portions	none	coarse
1948	?	1:40,000	B&W	yes/RC	complete	missing west end	coarse
1962	USFS	1:23,000	B&W	yes/RC	complete	complete	fine
1967	?	1:4,800	B&W	yes/RC	airport area	airport area	very fine
1979	NASA	1:60,000	CIR	yes/RC	complete	complete	medium
1984	USFS	1:15,840	true color	yes/RC	complete	west end only	fine
1996	NASA	1:60,000	CIR	no	complete	complete	medium
1996	NASA	6-ft pixel	B&W DOQ	yes/USFS	complete	complete	medium
2001	SWCA	9-in pixel	CIR DOQ	yes/SWCA	complete	complete	very fine

ecologically important changes over time.

I scanned and georeferenced Sarah Watson's vegetation map of the refuge (Watson, 1979) for comparison to my 1979 vegetation layer. Communities depicted on the Watson map—upland marsh transition, sedge dominant, and plantago—roughly correspond to my high marsh, low marsh and lower low (succulent) marsh, respectively, but the breaks were drawn somewhat differently. Some of the lower limits of my “sedge low marsh” were typed by Watson as “plantago.” On the other hand, areas that I mapped as high marsh in the upper limits of the wetlands were often typed as “sedge dominant” by Watson, so the total extent of low marsh sedge is roughly similar on the two maps.

The 1962 photos are impressively sharp. But black and white photography offers less information than does true or infrared color. There was a greater degree of speculation in my interpretation of these 1962 photos than for the 1979s. This is especially true of the high marsh/low marsh break. The tide was also fairly high in the 1960s, and water may have covered the lower portions of some of the low marsh. I think, however, that by working backwards in time, mapping 2003 and 1979 first before proceeding to 1962, I learned enough to locate the 1962 community breaks in roughly the correct position. My estimates of acreage in meadow, high marsh and low marsh for 1962 should be considered “ball park.”

Although the georeferenced photography from 1948, 1967 and 1984 was not used to create “vegtype” shapefiles for those years, the images were very useful for specific purposes. The 1967 shots, for example, are extremely detailed, and were used to double-check my interpretations for the 1962 layer in the airport area. The 1984s could similarly be used to verify interpretations from the 1979s using different color spectrum and greater resolution. The 1948 aerials show the Mendenhall wetlands before the

dredging of Gastineau Channel, and give an indication of the original tidal flow dynamics.

Future vegetation The fourth vegetation layer in accretion.mxd is for the future year 2025. At 0.6 inches per year of glacial rebound (Hicks and Shofnos, 1965, Roman Motyka, pers. comm.) the land will have risen approximately one foot in 2025. Other assumptions used in my future projection are:

1) The current high marsh/low marsh break (HMLM) occurs at approximately 16.5 feet. (this assumption may be altered when we have more complete topographic mapping for the refuge).

2) With one foot of rebound by the year 2025, today's 15.4-foot contour will become the ~16.5-foot contour. The HMLM break should migrate out to roughly that position.

3) The lower edge of the low marsh should migrate out to about the position of the current lower margins of the lower low (succulent) marsh (LL), and/or the algal mat communities (AL).

4) Uplift meadow (MD) will continue its advance into the upper reaches of the high marsh as the position of Extreme High Water changes. I have no contour lines or lower community positions to reference for the future MDHM break, and here relied on best judgement, from experience with current vegetation and apparent rates of advance in different parts of the refuge.

5) No further development will take place on the refuge or adjoining private wetland parcels. (If it were to occur, loss would be primarily to acreage of uplift meadow and high marsh types.)

In addition to the provisional 15.4-foot tide line provided by CBJ, I made use of the approximate zero-foot line mapped from the October 2002 low-tide photography (Appendix C). Although the low marsh will not approach

even close to today's zero foot line *elevationally* by the year 2025, the relative separation of 15.4 and zero lines gives a crude indication of slope of the terrain. In some places, such as the dredged portions of Gastineau channel, the 15.4 and zero lines are actually very close together on the horizontal dimension.

Terrain-slope will of course be much better established by future LIDAR-generated contours, and will allow more sophisticated modelling of future vegetational change.

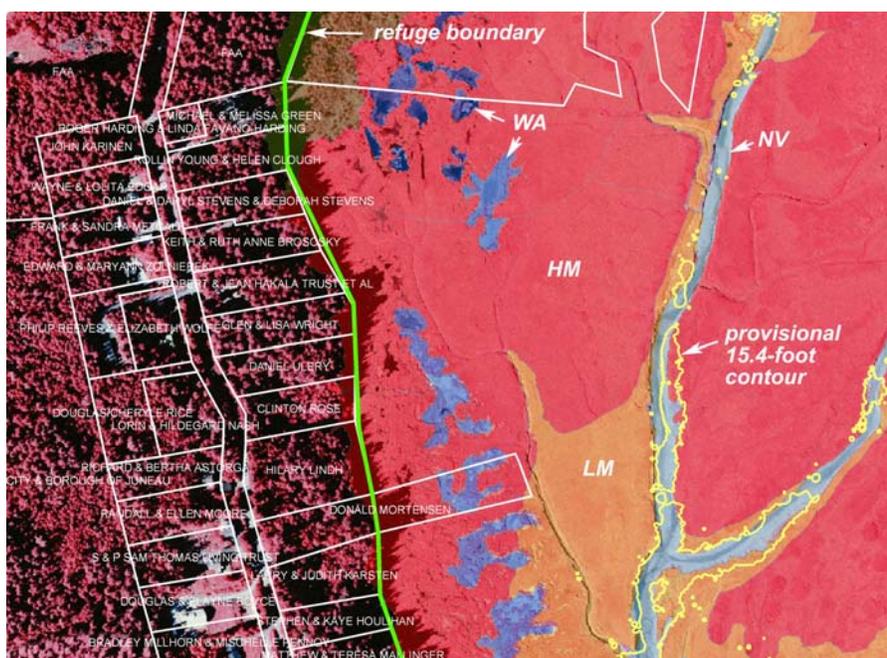


Fig 6 Sample from parcels layer for the Wigeon Ponds area near Mendenhall Peninsula. Private parcels are labelled with the “owner” field.

Layers for property boundaries The accretion.mxd project includes layers showing the airport and refuge boundaries, and another for private parcels adjoining the refuge. As with the 15.4 contour, these are to be used only by SEALTrust and collaborators for initial scoping purposes. Property boundaries (Fig 6) are not survey-grade accuracy on these layers. They should be useful, however, in identifying land owners in areas of conservation concern.

Interpreting map layers

Many patterns and trends emerge from an examination of the layers in this GIS project. We will describe a few, to demonstrate potential applications of the project. Each user will hopefully develop additional applications. “Accretion.mxd” is best considered an evolving analytical tool, rather than a final product.

Lower Mendenhall River oxbow

The impending cutoff of the tight oxbow loop on Mendenhall River *above* Brotherhood Bridge has received considerable attention recently, perhaps because of uncertainties about its significance to down-river development. Less attention has been given to a similarly narrow-necked oxbow just west of the airport (Fig 7).

In 1967 the dominant vegetation throughout the scene was Lyngbye sedge, which probably resulted in more frequent goose activity. Note also the dredging activity in the floatplane approach path. This would probably not be permitted today in light of what is known about attractiveness of dredge ponds to birds dangerous to aircraft.

By 1984, high marsh grasses (darker green) had extended out onto the oxbow neck, which had eroded on both sides, to only 200 feet across. Low marsh sedges (paler blotchy grey-green) occupied the lower river terraces)

In 2001 the neck was only 60 feet across. Sedge cover expanded on the muddy river terraces

Table 2 Oxbow neck erosion rate in feet per year, calculated for intervals between photography. Rates held fairly steady except for 1984 to 1996. At the most recent rates, the neck would be breached in 2005.

	width	loss	timespan	ft/year
1948	800			
1962	540	260	14	19
1967	440	100	5	20
1979	280	160	12	13
1984	200	80	5	16
1996	150	50	12	4
2001	60	90	5	18

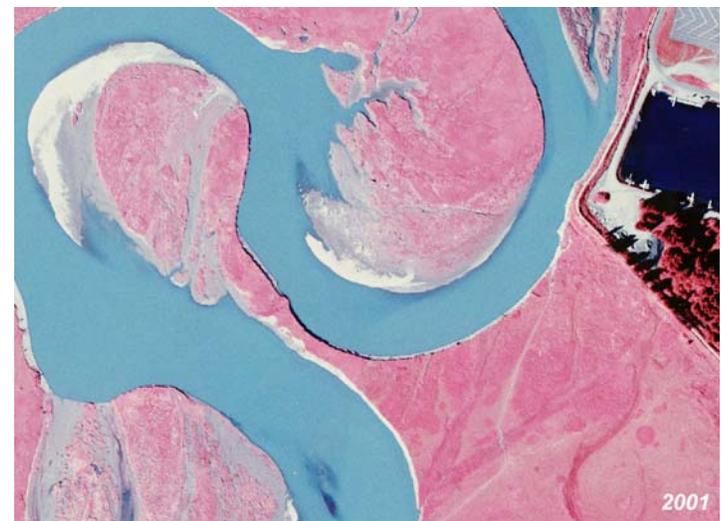
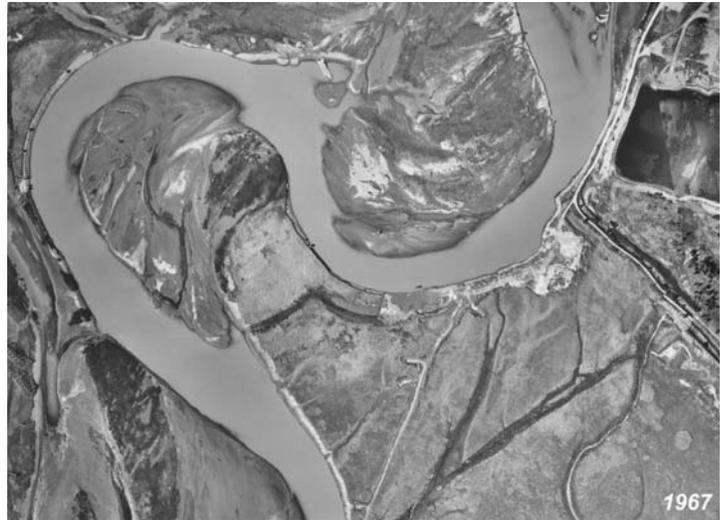


Fig 7 Historical series and predicted lagoon morphology, lower Mendenhall River oxbow. Lagoon will still connect on ~ 15 foot tides.

but was replaced by grasses in the upper center.

When the neck is breached, a tidal lagoon will form. This brackish pond, if no longer heavily scoured by river currents, could support ditch-grass and develop into exceptional fish and bird habitat. Unfortunately it is in the wrong location. Enhanced bird foraging opportunities will not be acceptable to the FAA.

Changes on the central refuge

Figure 8 shows 5 stages in the evolution of channel morphology and vegetational communities in the heart of Mendenhall wetlands. An examination of each photo will introduce some interpretive clues that can also be applied to other portions of the refuge in the accretion.mxd project.

1948 At first glance, the 1948 photo appears devoid of human influences. No road existed on Douglas Island. The right edge of the scene was the approximate tidal divide of Gastineau Channel. Tidal sloughs branched dendritically from left to right, but to the east of Bedrock Island (off the photo), they began to coalesce again.

Relative sea level was about 3 feet higher than today in 1948. The sea washed daily up to the forest edge, where today it visits rarely. The upper half of the scene was mostly bare tide flat transected by sloughs. Because there were few anthropogenic impediments to tidal flow (runway extensions, dikes, spoil islands, Egan Drive, etc), currents were likely stronger than today, scouring the flats and in many places preventing vascular plant establishment even where tidal elevations might have permitted it, given a bit more protection.

The mottled patterns on the flats just north of the forest were incipient sedge low marsh. White patches in the upper portion were topographically higher and thus drier than the darker wetted portions of the flats. They were probably a combination of natural berms created by tidal currents, and sidecast from early dredging activities. In the ArcMap (or ArcReader) project, examine the area eastward from this scene. A very narrow E-W precursor to the 1962 channel dredging operation is evident there and the white berms are more readily recognized as dredging spoils.

1962 Tide was higher in this scene, possibly covering the lowest portions of the

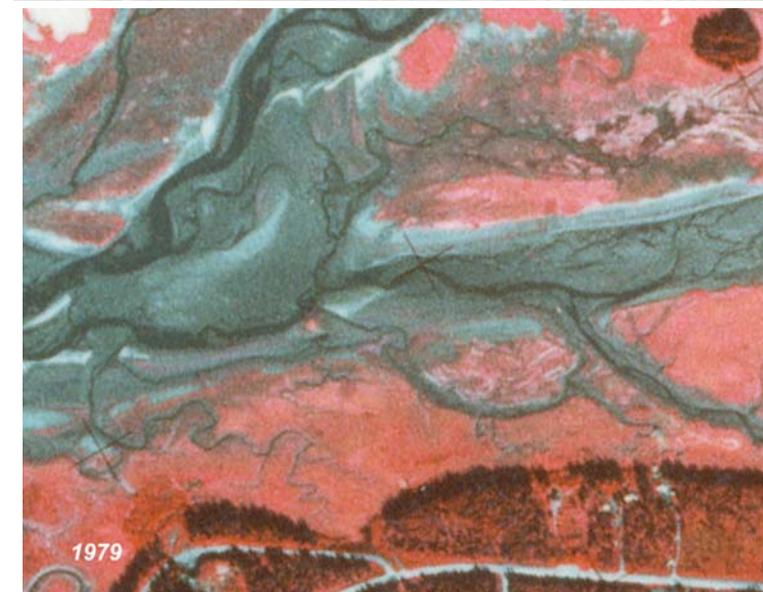
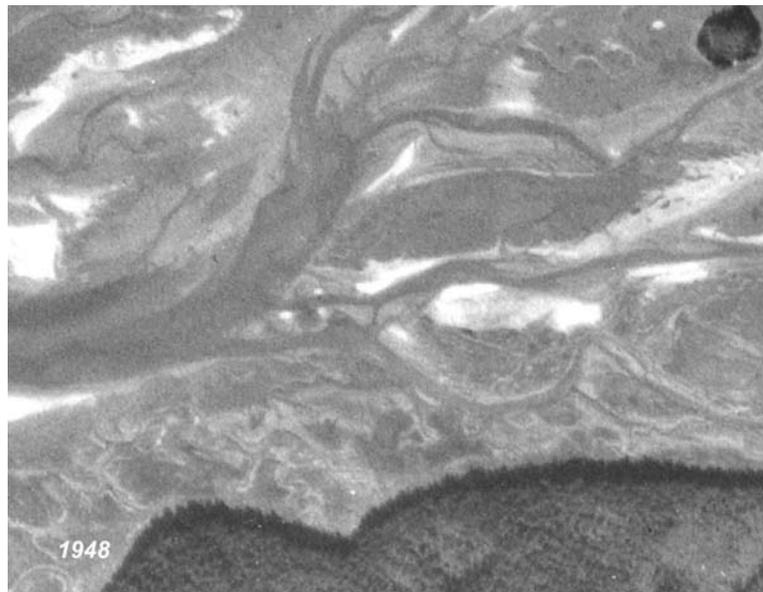


Fig 8 Five-part historical series for central refuge. At extreme lower left is a meander loop of Ninemile Creek, Douglas Island. Bedrock Island in upper right. Gastineau Channel in center.

vegetated marsh. Completely white areas were recent, unvegetated spoil piles from the deepening and broadening of Gastineau Channel to enhance small boat passage between downtown Juneau and Fritz Cove.

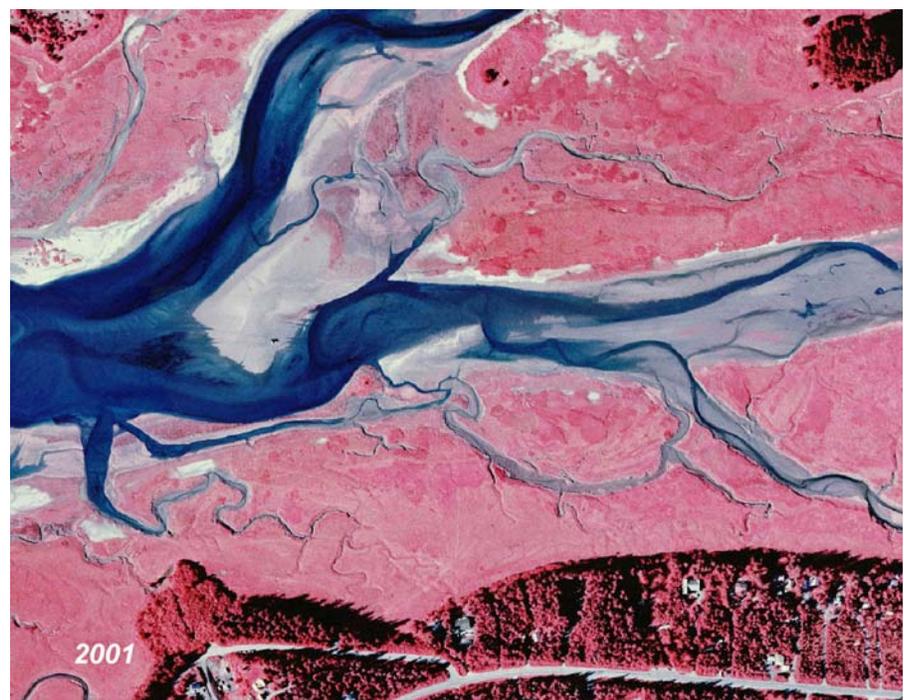
Relative sea level was 2 feet higher than today. The smooth grey portions of the flats were sedge low marsh, with more complete coverage than in the mottled 1948 photo. A road had been put in (but compare the 1979 alignment). No residential development had yet occurred.

1979 Tide was very low for this photography, and slough thalwegs (deepest part of channel) were clearly outlined. Peach tints showed the first colonization of grassy high marsh, which had replaced half of the former sedge low marsh on the Douglas side of the channel. High marsh was patchier on the north side, primarily invading the spoil islands. Low marsh was indicated by the paler pink tints, closer to the sloughs.

Five homes had been built in 1979. Fill intruded into the marsh in the lower left corner. This must have occurred shortly after the 1962 photos because it was already well colonized by alder in 1979.

1984 Relative sea level was only one foot higher than today. High marsh had almost finished its replacement of sedges south of Gastineau Channel. Darkest green circular patches were clones of rye grass invading the remnants of sedge communities. Pale grey areas on spoil islands showed retarded succession, probably because of substrate coarseness. These patches were washed by high storm tides, excessively drained, and hostile to seedlings during dry spells.

2001 Spruces invaded the spoil islands along the northern edge, but a few white patches showed areas that still resisted colonization. As in the 1984 true color photo, darker circular patches showed grass clones establishing in sedge low marsh. Generally, however, the colors are hard to interpret in this photo, and ground-truthing was necessary for us to draw the high marsh/low marsh break shown in the veg2003 layer. The last substantial patches of low

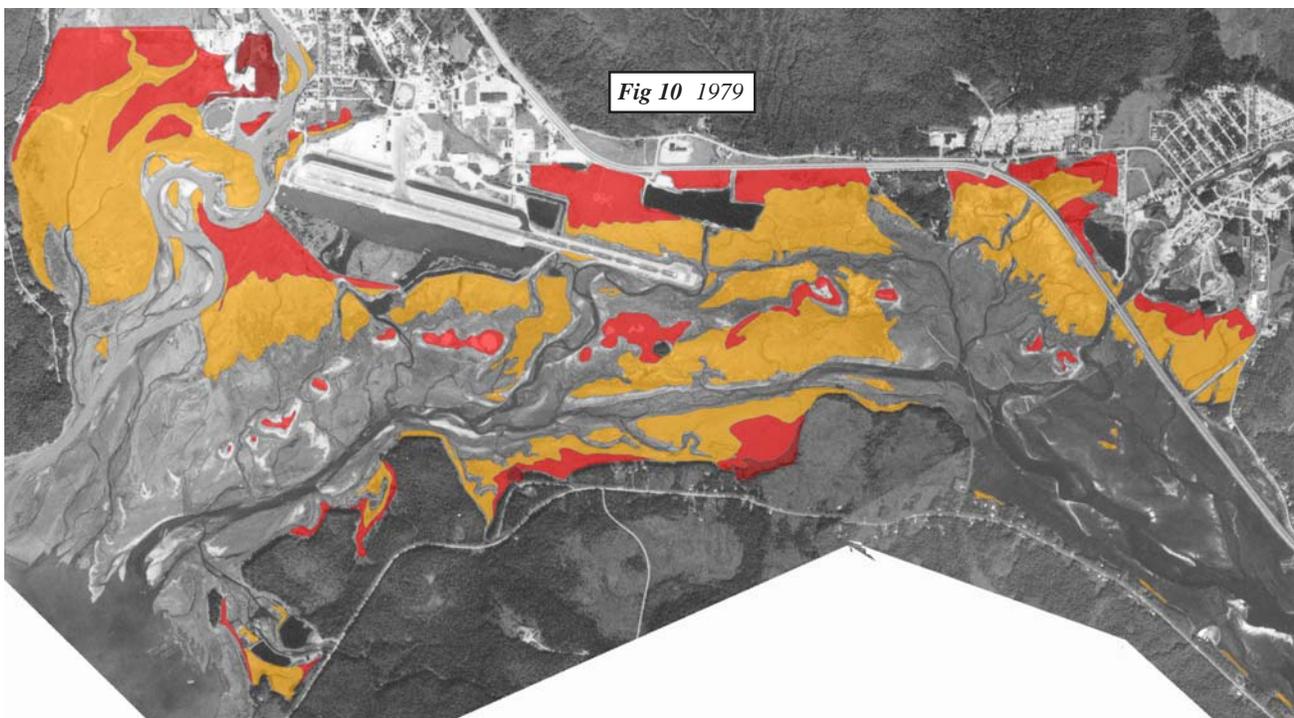
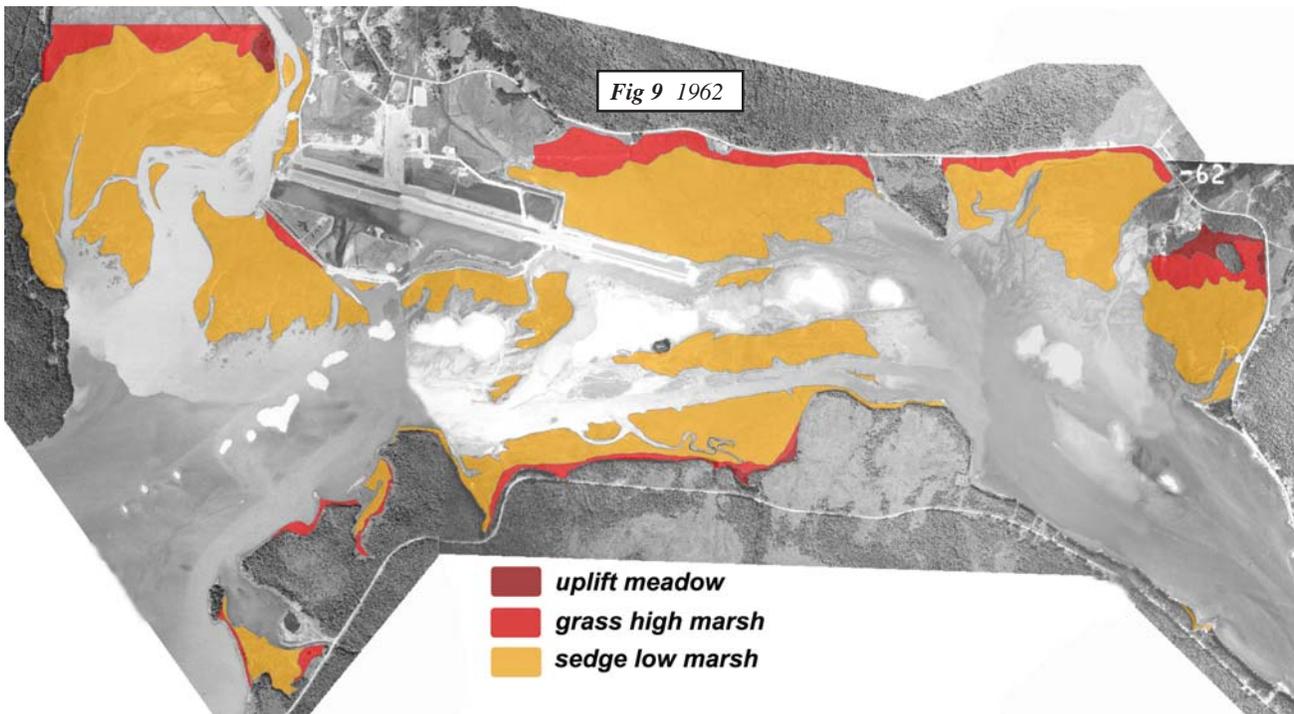


marsh were in the upper left, lower left and upper center. Because sedge low marsh is disappearing from the Douglas Island side of the refuge, avian grazers like geese now make little use of this area (Armstrong *et al.* 2004)

Sixteen houses appeared in this scene. The current CBJ parcels layer shows 25 lots north of the highway.

Refuge overview: past, present, and future

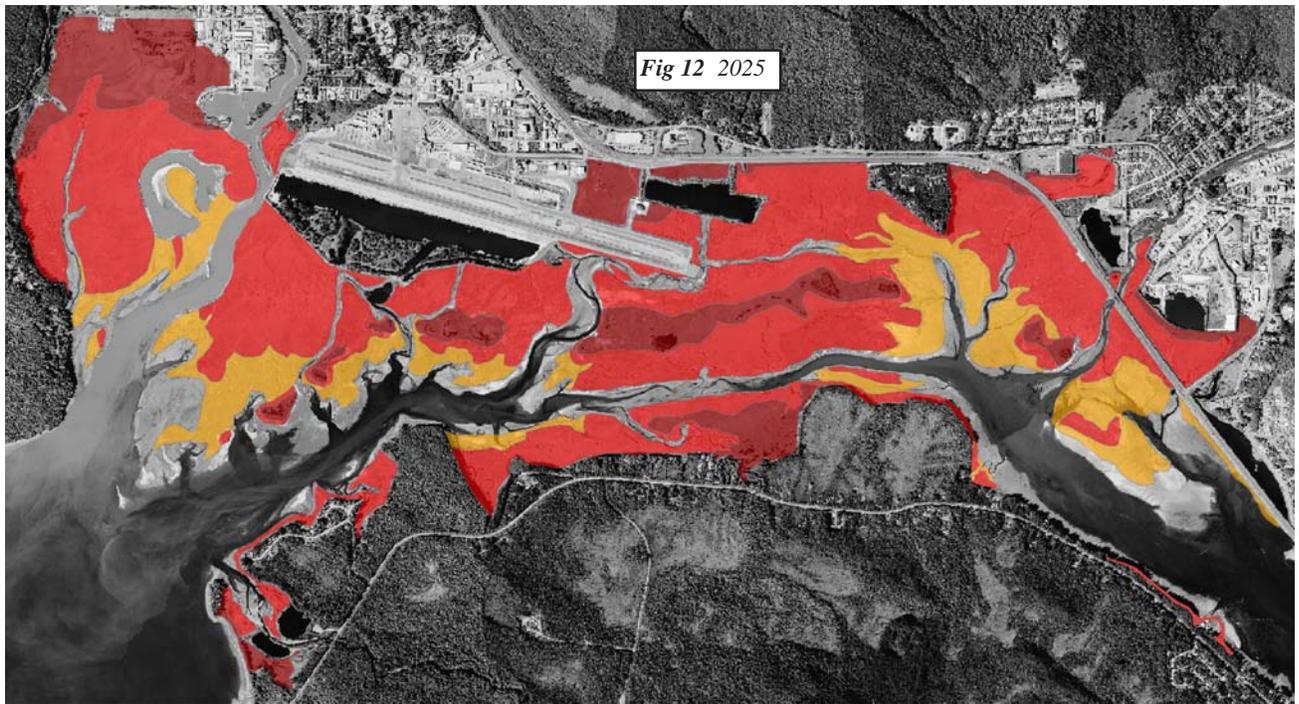
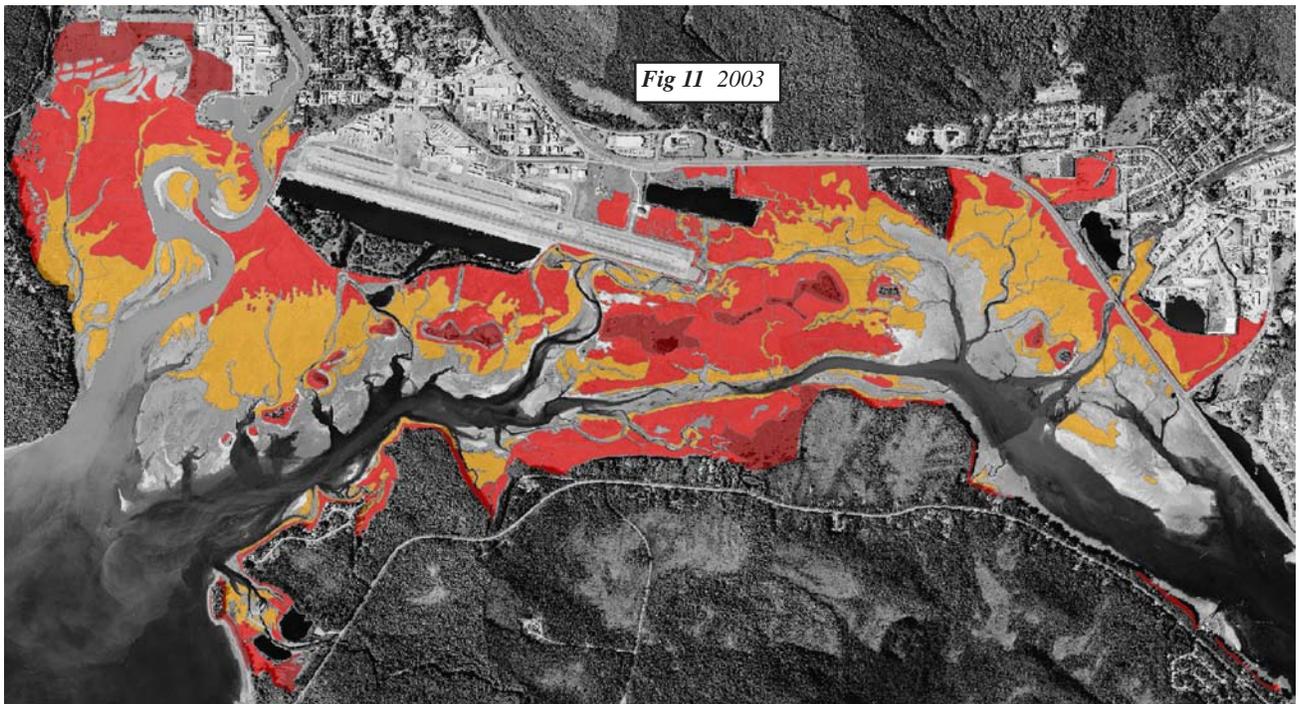
Direct examination of the georeferenced historical photos reveals details of change and trend for specific areas. But to analyze refuge-wide patterns, it is also useful to have GIS shapefiles that identify key community types. From these layers, total acreages can be tallied by type and



year. Figures 9 through 12 show vegetation status in 1962, 1979, 2003, and a projected map for 2025. All background photos were made black and white for easier comparison of vegetation color codes. The final veg map for 2025 is based on the same SWCA 2001 imagery as the map for 2003 with one exception; the oxbow area has been altered to reflect the expected neck cutoff and lagoon formation. There will of course be anthropogenic changes, but these are harder than vegetational change to predict.

1962 In 1962 there were roughly 1300 acres of

sedge-dominated low marsh habitat (Fig 9 & 13). This may have been the greatest acreage attained by sedges since the waning of the Little Ice Age. We lack estimates for earlier periods like 1948 and 1929 because of inadequate photo resolution and incomplete coverage. But, as indicated in our case study of the central flats, low marsh may have been partially inhibited by strong tidal flows prior to mid-century. The striking line of white patches—bare spoil islands—running through the center of Figure 9, combined with the recent eastward runway extension,

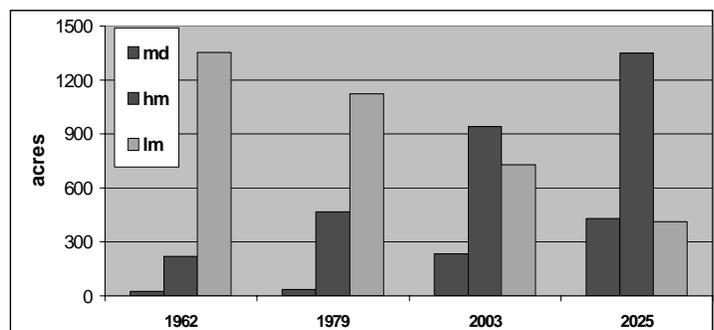


severely altered the original tidal flow patterns.

There was only a relatively thin belt of high marsh grasses along the borders of the Mendenhall Wetlands, and little of it was within the refuge as currently defined. Relative proportion of low marsh to high marsh in 1962 would be even higher if non-refuge lands were excluded from our acreage totals.

1979 By this time, grassy high marsh had advanced well out into the refuge in some areas, doubling in acreage over the 1962 levels, while sedge low marsh declined commensurately. Advance of low marsh into former bare mudflat did occur, but not to

Fig 13 Acreages of three vegetation types shown in Figures 9 through 12.



		1962	1979	2003	2025
<i>Change in acreage over time</i>	uplift meadow	26	35	234	432
	high marsh	219	465	941	1349
	low marsh	1353	1123	727	413

the degree that it was lost to grass invasion from above.

Construction of Egan Drive heavily impacted fish and wildlife habitat in the Lemon Creek area. Dredge ponds and landfill proliferated, and what remained of the once-rich tidal marshes northeast of the new expressway was now washed only via culverts.

2003 The period between 1979 and 2003 saw the greatest losses in low marsh acreage: from 1123 down to 727 acres. At the same time, grassy high marsh roughly doubled, from 465 to 941 acres. In the area between Temsco and Sunny Point, low marsh sedges do occur, but they are mostly confined to the inner terraces of branching sloughs.

While greatly reduced from former times in terms of acreage, these linear sedge habitats are extremely important to birds and fish. Although no studies have addressed the phenomenon, it is possible that the terrace sedges may persist longer than might be expected from rates of glacial rebound. Tidal scour could potentially grade the sloughs downward as surrounding flats rise. Because these narrow belts of low marsh sedges may eventually be all we have left on the refuge, more investigations of succession and tidal dynamics along slough systems are warranted.

For the first time in the historical series, substantial coverage of uplift meadow—234 acres— appears on the 2003 vegetation map. In 1962 and 1979, uplift meadow was almost non-existent on the mapped portions of Mendenhall wetlands. But it had formerly been widespread to the north of the mapped area, in both the lower Mendenhall Valley and at Lemon Creek. For about a century following the waning of the Little Ice Age, glacial rebound had been shifting former tidal salt marsh into supratidal elevations. The result was a rich herbaceous meadow of very high value to grazing mammals like deer and bear. These unforested but well-drained coastal habitats made ideal building sites, and were quickly replaced by industrial and residential development, as can be seen by a comparison of Figures 9 and 10 north of the airport and in Lemon Creek.

Uplift meadow is a globally rare habitat (see discussion in our report to SEALTrust on the Amalga-Eagle area, Carstensen, 2003). Certainly it is less important than the frequently flooded tidal habitats to migratory waterfowl and shorebirds, but it offers superb foraging habitat for resident mammals and nesting songbirds. The Mendenhall Refuge may be poorly situated to retain substantial acreage of low marsh communities, given continued glacial rebound and human barriers to tidal flow. But it is ideally situated to “capture” increasing acreage of uplift meadow (Figs 11, 12 and 13). Managers may want to plan for this shift in habitat values by maintaining or enhancing access corridors into the refuge for deer, bear, and other mammals, especially on Douglas Island and off Mendenhall Peninsula.

2025 During the next quarter century, our low marsh sedge habitat will again be reduced, perhaps by as much as in the preceding 25 years. The amount and configuration of loss will vary throughout the refuge. In the central portions, only thin belts of sedge will remain along sloughs. Along Mendenhall River, and southeast of Sunny Point, prospects are brighter for retaining enough acreage to support grazing and seed-gleaning waterfowl, and other wetland functions such as maintenance of the invertebrate prey base for summering salmonids, sculpin and flounder.

The southward migration of low marsh habitats may help to draw waterfowl—probably the most dangerous of the groups of “birds of concern”— away from the airport area. Currently, Canada Geese are disproportionately concentrated near airport facilities for both foraging and resting (Armstrong *et al.* 2004). Redistribution of birds in response to vegetational changes could therefore improve airport safety to some degree.

On my predicted vegetation map for 2025, acreage of uplift meadow is projected to double over the current amount, from 234 to 432 acres. A large percentage of the gain, however, will be on unprotected private lands, and so these areas may well be developed instead. Much of the predicted meadow habitat north of the runway is slated for airport expansion. And although the northwest corner of the 2025 map is shown as potential uplift meadow, industrial expansion or further golf course development will likely prevent that.

Recommended research

The following list of research needs for the Mendenhall Wetlands is limited to those most directly related to this mapping project. For more research and management recommendations concerning the refuge, see Armstrong *et al.* (2004), chapter 10.

- **John Crow research** The historic and repeat vegetational measurements conducted by John Crow should be summarized and made available. The Crow site locations and associated data would be valuable additions to this and other GIS projects.

- **Substrate composition** explains much about marsh community distribution and successional trajectories. The succulent low marsh and barnacle/mussel/rockweed communities, for example, seem to require coarser substrate than does sedge low marsh. It would be valuable to have a comprehensive “sediment-size” layer for this GIS project. Data should be keyed to GPS waypoints. Unlike vegetation mapping, sediment-size surveys would be most efficient during plant senescence.

- **Vegetation communities and fish** The Auke Bay Laboratories (NMFS) have a great deal of data on distribution and phenology of marine and anadromous fish on the Mendenhall Wetlands. These data should be integrated with this GIS project, to examine correlations between fish distribution and vegetational communities.

- **Slough incision** Study should be conducted on

tidal flow velocity and erosion in sloughs supporting sedge low marsh along inner terraces. Are these sloughs being incised downward, partially countering the effects of glacial rebound? (See also note below on habitat enhancement.)

• **Modeling vegetational change** Projected future vegetation presented in Figures 12 and 13 is based upon provisional and incomplete contour information. For now it is the best we can do, and should provide a starting point for discussion of adaptive refuge management strategies. It could be some time before a final draft of LIDAR-generated contours for refuge is prepared, validated by ground survey, and formally accepted. At that time, a more finely tuned model should be developed that matches past and present vegetational distribution to known (and inferred historic) elevational position as well as sediment size (see above) to create maps of predicted community distribution at selected times in the future.

This modeling exercise will be relevant not only to the Mendenhall Wetlands, but to estuaries throughout Southeast Alaska. We don't know, for example, whether the loss of low marsh communities on the Mendenhall (and at Eagle River to the north) is an anomaly or the norm for tidal estuaries in the glacially uplifting portions of northern Southeast. A model incorporating vegetation, elevation, substrate and rebound rate, developed locally on the Mendenhall Refuge, could be applied to other key estuaries in an assessment of regional trends. Because of its accessibility and long history of study, the Mendenhall is the best place to build such a model.

• **Mammal corridors** - Increased acreage of uplift meadow along the forested refuge borders will make these areas more important for deer, bear, porcupine, and small mammals in the future. The potential to observe or track these mammals will become an added attraction to a refuge where birding and waterfowl hunting are presently the most popular recreational activities. Current use of the wetlands by these mammals should be investigated, particularly in regard to access corridors. Almost all access is currently through private lands. A strategy for maintenance and enhancement of access should take into account the potential impacts of dogs on wildlife. (Armstrong *et al.* 2004).

• **Potential land accretion** Examination of the properties layer (Appendix B) shows that the key areas along the refuge boundary where private parcel accretion could greatly impact wetland values are eastern Mendenhall Peninsula and Douglas Island from Ninemile Creek estuary east to Hendrickson Point. Additional areas include Sunny Point, Fish Creek estuary and eastern Bayview subdivision.

Although our future vegetation map predicts loss of valuable sedge low marsh communities off Mendenhall Peninsula, the Wigeon Ponds will continue to provide first class wildlife habitat for birds, mammals, and amphibians. In comparison, the Ninemile-to-Hendrickson stretch may have somewhat lower values for most wetland birds,

but equal or greater value to grazing mammals, simply because Douglas's source populations of deer and bear are less fragmented than Mendenhall Peninsula's.

The Hotspots study (Armstrong *et al.* 2004) collected only limited bird-use data for the Mendenhall Peninsula and Ninemile-to-Hendrickson wetlands. Because of the obvious strategic importance of these areas, further wildlife surveys are warranted.

• **Habitat enhancement** Completely accidental creation of excellent terrestrial and aquatic wildlife habitat between the Dike Trail and floatplane landing pond suggests there is also great potential for directed artificial enhancement on the Mendenhall Refuge. But we have little experience with methods and results of intentional habitat manipulation. Small scale experiments with created ponds and sloughs should be conducted soon. These limited experimental manipulations would have low environmental risk, but could provide the needed knowledge for planning of future more ambitious habitat enhancement projects.

New ditch-grass ponds at greater (i.e. safer) distances from the airport would prove highly attractive to waterfowl and fish-eating birds like heron, tern, merganser and kingfisher, and would also become popular wildlife viewing areas. Artificially deepened and widened sloughs, in areas where grass is currently replacing sedges even on the lower marginal terraces, might help to perpetuate this critical marsh community. Given the present and projected plentitude of grass high marsh community, this type seems to be the best candidate for experimental conversion to created ponds and sloughs.

• **Second crossing** All of the above-mentioned research needs are directly relevant to the evaluation of options for a second crossing of Gastineau Channel. Consultants for that project will have the funding to address many of these research needs. SEALTrust and regulatory agencies could help to ensure that this information is collected, and applied to the study of channel-crossing options, as well as conservation strategies for the Mendenhall Wetlands State Game Refuge.

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Bob Christensen and Cheryl Van Dyke of SEAWEAD provided essential GIS guidance from conception to completion.

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Appendix A

Common and scientific names for selected plants of the tidal marsh.

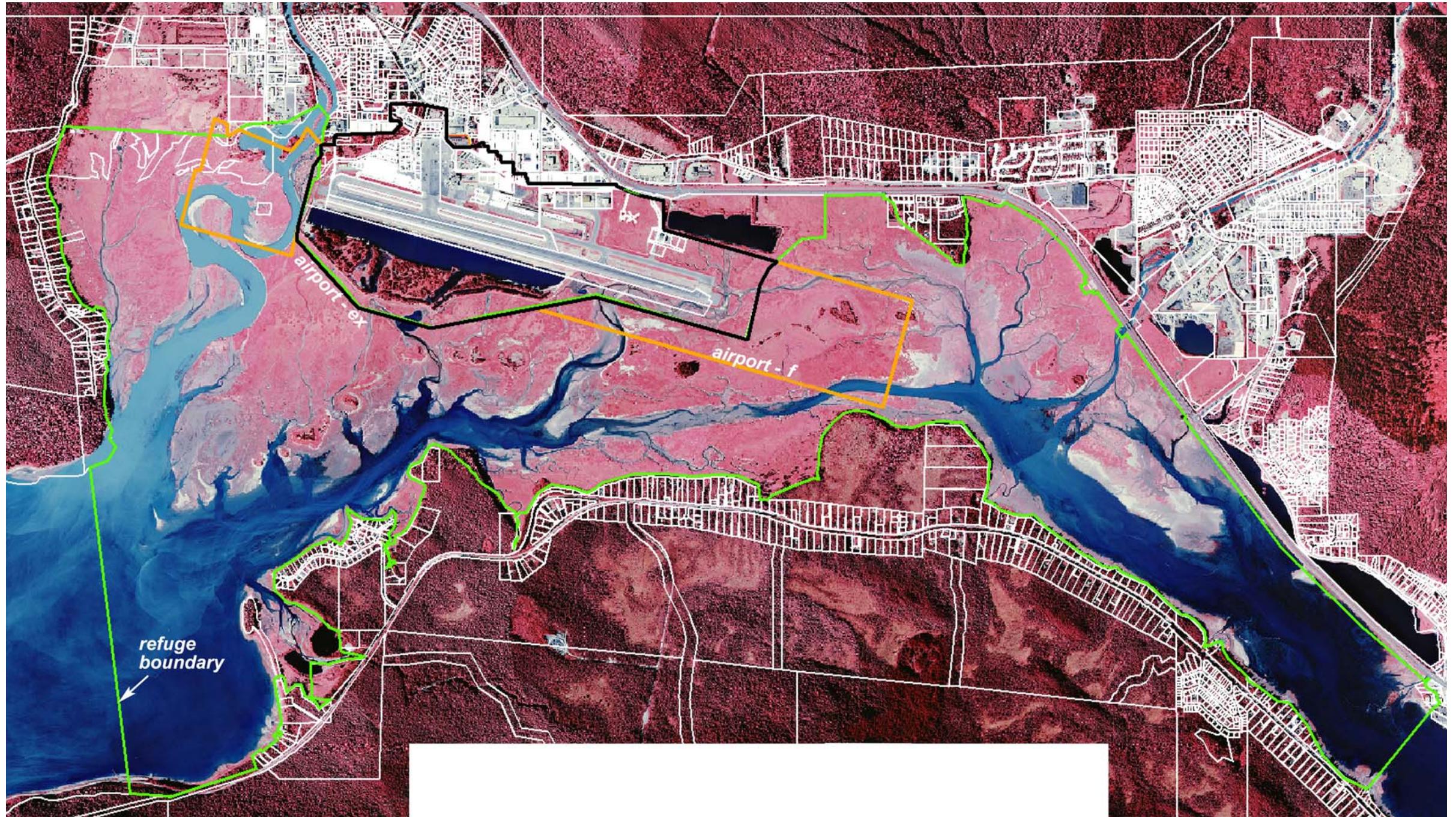
Common names for plants used in text follow Pojar and MacKinnon. 1994

Vascular plants

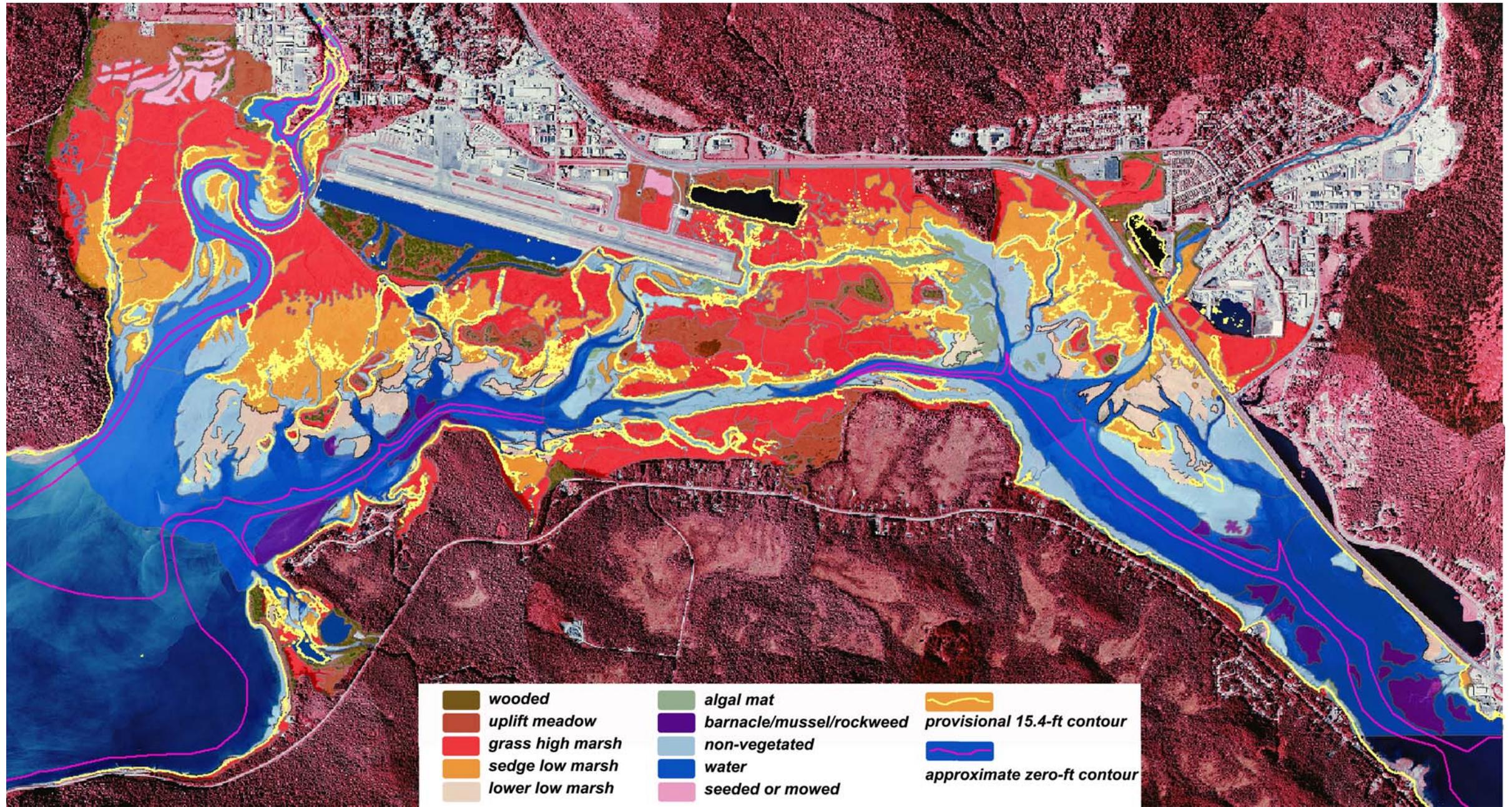
alkali grass	<i>Puccinellia nutkaensis</i>
arrow-grass	<i>Triglochin maritima</i>
ditch-grass	<i>Ruppia maritima</i>
foxtail barley	<i>Hordeum jubatum</i>
goosetongue	<i>Plantago maritima</i>
hair grass	<i>Deschampsia caespitosa</i>
Lyngbye sedge	<i>Carex lyngbyei</i>
rye grass	<i>Elymus arenarius</i>
sea milkwort	<i>Glaux maritima</i>
Sitka spruce	<i>Picea sitchensis</i>

Algae

rockweed	<i>Fucus distichus</i>
"mat algae"	<i>Vaucheria sp</i>



Appendix B Property boundaries



Appendix C Vegetation 2003, and contours: Mean High Water (15.4 foot, provisional, LIDAR-generated) and Mean Lower Low Water (from photography on zero-foot tide)