Arctic Impressions

A Photographic Journey along Alaska's Arctic Coast

Exhibit compiled by
Mandy Lindeberg, Tahzay Jones, Catherine Coon, and John Harper

Photographs selected by Mandy Lindeberg, Tahzay Jones and Catherine Coon
Photo editing and exhibit printing by Mandy Lindeberg
Preface by Tahzay Jones
Photo annotations by Dr. John Harper, Coastal and Ocean Resources, Inc.
Booklet prepared by National Park Service

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Acknowledgements and Photography

We gratefully acknowledge the support of organizations working in partnership for the Alaska ShoreZone effort, including over 40 local, state, and federal agencies and organizations. A full list of partners can be seen at www.shorezone.org. Several organizations stand out as being the earliest or staunchest supporters of a comprehensive Alaskan ShoreZone program. The Board of Directors of Cook Inlet RCAC supported the earliest Alaska surveys and continues to develop applications for ShoreZone imagery and data. The staff at NOAA's Alaska Fisheries Science Center Auke Bay Laboratories and the Alaska Regional Office have taken on a leadership role and are responsible for efforts to coordinate the completion of a state-wide ShoreZone program and to integrate and deliver imagery and data to any user. The Nature Conservancy has provided outreach and organization to Alaska ShoreZone partners and ensures the continued coordination of survey and mapping efforts. Alaska ShoreZone imaging and mapping in the Arctic has been led by the Bureau of Ocean Energy Management, National Park Service, Arctic Landscape Conservation Coalition, and NOAA Fisheries. Special thanks to Nuka Research and Planning Group, LCC for conducting ShoreZone surveys on the North Slope.

Photographers

ShoreZone imagery acquisition relies on multiple field crews to facilitate the gathering of both video and digital still photographs and specific aerial surveys are for particular sponsoring or funding organizations. Thus, imagery collected during ShoreZone surveys is a product of Alaska ShoreZone rather than individual photographers. However, two of the most experienced Alaska ShoreZone survey team members have flown as the biologist/photographers for most of the Alaska ShoreZone surveys. All of the aerial photographs presented in this exhibit were taken by Mandy Lindeberg and Mary Morris.

Photo Access and Referencing

All photographs presented in this exhibit are from the Alaska ShoreZone program and are available for non-commercial use and accessible at www.shorezone.org or http://www.alaskafisheries.noaa.gov/shorezone. Use of this imagery should reference Alaska ShoreZone.

Preface

Think of the Arctic and what comes into your mind's eye? For most, even the word Arctic conjures up images of a frigid, inhospitable, snow covered wasteland, sprinkled with the occasional polar bear, and not much else. Nothing could be further from truth.

The Alaskan Arctic can be a verdant and colorful landscape supporting a vast array of plants, animals, and even people. These remote and almost inaccessible Arctic communities have learned to take advantage of the rich resources available in all shapes and forms; nurturing an appreciation for the action of dynamic elements found along the coast. This spectacular coastline is always shifting; even more so now that sea ice leaves the coast earlier in the summer and returns later in the fall. The Arctic coast, still remote and inaccessible even by Alaskan standards, is changing even before most will ever know it.

The Alaska ShoreZone program has been able to document Arctic coastal biology and dynamic processes through high resolution aerial imagery, videography, and ground assessments: a snapshot in time of the ever changing Arctic coast. Some of the most spectacular of these images have been collected in this volume, Coastal Impressions: A Photographic Journey along Alaska's Arctic Coast. Glance through these pages, study and ponder over them , then close your eyes and imagine. Wipe away your preconceived notions of the Arctic and learn about the gem that is the true Arctic coast.

Each photo has been annotated by experts trained to read the language of coastlines and what they see within each image. Which photos draw your attention and why? What do you see in them? Compare your coastal impressions with the expert's descriptions or simply enjoy the photos beauty alone. Either way, we can all agree Alaska's Arctic coast is stunning with incredible patterns which are ever changing.

ShoreZone

ShoreZone is a coastal classification and mapping system based on the collection and interpretation of aerial imagery of the coastal environment. The imagery is taken at 100-300 meter altitude at an oblique angle while flying just offshore and is geo-referenced to the helicopter track-line. Video and still photographs are captured by a geomorphologist and biologist as they synchronously record audio commentary about specific shoreline features. The video, digital stills, and audio data are later used to map coastal features such as wave exposure, substrate type, sediment texture, intertidal and very shallow nearshore biota. In order to map the most comprehensive shoreline data possible, surveys are flown during the lowest tides in late spring and summer to ensure that the surveys capture the entire intertidal zone.

ShoreZone methods were initially developed in the 1980s to map coastal features in British Columbia for the Provincial Government and through the 1990s in Washington for their state government. The objectives were to use imagery to produce a searchable inventory of geomorphic and biological features that could provide habitat maps for coastline resource management and oil spill planning and response. Over the years ShoreZone imagery and habitat maps have been used by coastal resource managers, researchers, and educators.

In 2001, Cook Inlet RCAC initiated ShoreZone aerial surveys for Cook Inlet and the Kenai Peninsula and sponsored a pilot program to deliver ShoreZone imagery and data on-line for the first time. While the imagery has always been key for interpreting and mapping shoreline features, the development of the Alaskan ShoreZone program coincided with advances in technology that allowed the imagery to take an even more important role. Now, sharing web-accessible ShoreZone imagery and data has become not only a reality but a priority.

The Alaskan ShoreZone program has expanded the project throughout the Gulf of Alaska and the Arctic, and is now focusing on Western Alaska, and the Aleutians in the future, to complete the entire coastline of Alaska and make that information available to the public.

Introduction

In this exhibit you will see dozens of spectacular photos of the arctic coastline. The images were collected along 10,000 km (6,000 mi) of shoreline in Alaska during the arctic summer (July and August) of 2012 and 2013. Many of the images were selected for their artistic composition – sculpted shapes, mosaics of colors or juxtaposition of odd features. Each image tells a story. The arrangement of forms reveals how these features were created, as well as the rate of change over time. This overview, in addition to the captions, provide insight into the landforms within the image and the significance of these features within the broader arctic ecosystem.

Reading the Landscape

The lush greens captured by the images allude to the short growing season of the wetland and tundra vegetation. Every image includes some part of the Bering, Chukchi or Beaufort Seas – sometimes churned by brisk winds but mostly showing near glassy calm waters. What you do not see is white – winter lasts eight to nine months each year. You will not see the winter sea ice that abuts the shore, limiting waves and storm surges, sometimes completely overriding the barrier islands. However, even during the summer, pack ice may be close offshore limiting the growth of large waves.

Another type of ice that you will not see is the pore ice that exists within the coastal sediments creating the rock-like substrate referred to as permafrost. Virtually all the landforms and landscapes in these images are bonded by ice, despite the lush green surface vegetation. In most areas the ground thaws less than 0.5 m (1.5 ft) deep, while deeper layers remain frozen year-round. Visible clues to the presence of permafrost are the polygonal fracture patterns on the tundra surface. Each winter the surface of the tundra becomes so cold that it contracts and eventually cracks. As this cracking process is repeated over hundreds of years, the polygonal fracture patterns become part of the landscape. So, although you cannot see the ice, the landforms tell you that it is there.

There is a clue in each image about the processes that are responsible in shaping the landscape. From the missing sea ice, to permafrost, to storms that cause cliff erosion and recurved-spit deposition, to the extensive flooding associated with storm surges (as indicated by stranded log lines), the dynamic processes that shape the Arctic are only hinted at in these images. We hope that the brief process descriptions will help these images speak to you.

Shore Types and Processes

Shore Type

Shorelines can be categorized into two general classes: hard shores comprised largely of bedrock and resistant to erosion and soft shores of sediments that are sensitive to erosion. Along the Alaskan Arctic coast hard shores are rare,typically forming steep cliffs with little to no beach. The majority of the coast is soft shoreline of sands, gravels, peat, silt and clay, generally bonded by permafrost. Soft shores show many different landforms including eroding cliffs, barrier islands, spits, deltas, large wetlands and expansive tidal flats.

Soft shores have to be melted and then eroded, resulting in some very unusual coastal landforms that are unique to the Arctic. Eroding shores can retreat at very high rates – as much as 30 m (100 ft) in a single open-water season. During erosion sediments may be transported along the coast and deposited. Permafrost areas also include considerable volumes of ice causing the land to settle below sea level (thaw subsidence) as it melts. Many of the images show a tundra surface visible through the shallow waters as the sea advances overland (inundated tundra).

Not all shores are eroding. Some of the barrier island complexes have been growing seaward for thousands of years. Wetlands, often comprising more than 50% of the shoreline length within a region, may be growing or eroding.

Coastal Processes

Sea Ice-

From October to July, much of the Arctic coast is locked in ice frozen against the coast (landfast ice), showing little movement over the winter months. In some locations, tongues of ice push inland across barrier islands and even up cliff faces, altering the landscape. One of the most significant impacts of sea ice is the limitation of wave development. This can leave most shoreline processes frozen and inactive for 8-9 months each year.

Wave Action-

Although waves only occur during the open-water months, they are the dominant process modifying the coast. Wave action causes erosion, sediment transport alongshore, and sediment deposition . Offshore pack ice limits the distance over

which waves can be generated, so even during open-water months, Arctic shorelines do not experience large oceanic swells. Waves generated during storms contain most of the energy that modify the coast. As such, the landscape often reflects these infrequent but high-energy storm events, in the form of recurved spits. Geologists refer to this as episodic uniformitarianism, where the landscape is created by infrequent but very high energy events.

River Discharge-

Some say that the Arctic has no spring season– only winter and summer. The rapid transition of the tundra from snow-covered to green grasses only takes a matter of days. The melting snow fills the creeks, which peak in discharge and then almost immediately dry. This event produces a large spike in river flow, often flooding over the surface of the still frozen lagoons and sea ice, before finding its way below the ice through surface cracks. This flooding pattern often produces odd depositional patterns at the delta fronts.

Wind-

Winds are very important in creating waves, generating meteorological storm surges and even moving sediments along the coast. Storm winds generate the waves that are the primary modifier of the coast. The same storm winds may also generate surges that far exceed the normal tidal range. Surges of 3m (6 ft) or more inundate large areas of the tundra, as evident by stranded logs as much as 5 km (3 mi) inland. These surges and the flooding associated with them may also melt the thermally sensitive permafrost, contributing to thaw subsidence or enlargement of thaw lakes.

The most observable effect of wind is in the formation of sand dunes. Dune development is largely absent along the Beaufort Sea coast but very common on the Chukchi Sea shorelines. Most of the Chukchi coast dunes grow parallel to shore, but erosional blow-out dunes also occur.

Tides-

The tidal range along the Beaufort Sea coast is less than 0.5 m (1.5 ft) and is dominated by the surges associated with high wind events (often referred to as meteorological tides). Tidal ranges are greater in the Chukchi Sea, reaching close to 1.5 m (5 ft).

Climate Change-

Most people are aware that coastal areas are sensitive to rising sea levels, and the Arctic is no different. Much of the coast is very low in elevation with previous tundra flooding recorded by stranded loglines and altered vegetation -large sections of shoreline show inundation of 100 m (300 ft) or more. These same areas will be affected by sea level rise and storm-surge inundation.

Sea ice is breaking up earlier and freezing up later, resulting in longer open-water seasons with the pack-ice edge much further from land, leaving more open-water over which waves can be generated. This situation leads to a more energetic wave climate. Larger waves and more energy translate into more coastal erosion and sediment transport.

There is a great temperature differential between the land (averaging around -10°C) and the sea (-1 to 2°C), meaning the sea has the capacity to melt the land, in addition to eroding it. Once the temperature is above 0°C, it melts and becomes a soft squishy mass that is easily eroded and transported away – gone forever. This is a landscape literally melting away. In low tundra areas ice within the tundra melts and the entire land mass slips below sea level with landform and vegetation still visible through the encroaching sea. Many of the images in this exhibit dramatically illustrate this change.

Wilderness-

You do not see much evidence of human influences in these images. Most of the images give the impression of a vast wilderness. But people have been using this coastline for thousands of years and the coast has provided livelihood for generations. There are very few points or bays that are unnamed. Good hunting spots may be revealed by a seemingly casual pile of logs that are used as a hunting blind and are likely to belong to a particular family. Land fast ice – ice locked against the shoreline with minimal pressure ridging – is a highway for travel between villages and camps. This highway is erased each spring by breakup. The main point is these images do not capture many of the subtle but important cultural aspects of the landscape that have persisted for millennia.

Oruktalik Entrance, near Tapkaurak Pt.

Endlessly Hooked *N 70 4.741 W 142 58.033*

August 2, 2012

This long, skinny barrier island not far from Cape Simpson is very typical of the Beaufort Sea coast. It is narrow, mostly devoid of vegetation and overwashed by waves generated in the Beaufort Sea (to the right). In fact, a wave can be seen overwashing at the lower portion of the photo. During winter months, sea ice may override the barrier islands (*ice override or ivu*). These barrier islands enclose wide, shallow lagoons. The wave overwash processes are causing a landward migration (to left), in some locations as much as 25 m (75 ft) per year. A number of spits are formed along the lagoon shore (left side of barrier island) and these are formed by wave transport, especially during storms.

Oruktalik Entrance, near Tapkaurak Pt.

Reaching for Closure *N 70 4.657 W 143 1.264*

August 1, 2012

Inlets through the barrier island systems allow water exchange between the Beaufort Sea (upper) and Oruktalik Lagoon (lower). Longshore sediment transport caused by waves is evident as the small fingers of sediment (spits) at the tips of the barriers island. Each spit likely represents a pulse of sediment deposited during a storm. The tidal channel is evident as it extends into the lagoon – here strong currents scour the channel and prevent the inlet from being closed by the spit formation. Although the tidal range is only about 15 cm (6 inches), storm surges can be in excess of 3 m (10 ft) and strong currents through the inlets during normal tides and storm surges keep the inlet open. Occasionally, inlets will be filled by sediment and closed, with a new inlet forming nearby.

Jago River Delta

Eye of the Tundra *N 70 5.524 W 143 19.122*

August 2, 2012

The Beaufort Sea coast reveals an amazing juxtaposition of landforms, in this case a nearly circular thaw lake next to a river channel in the Jago River delta. The tundra of the North Slope is covered with thaw lakes. The lakes form through a combination of thawing permafrost and wave action during the short summer. This river channel is slowly cutting into the bank near the thaw lake and cracks are visible near the rim of the lake, where the bank is collapsing. Sand flats in the upper portion of the photo are washed over during the spring freshet, when the rapid snow melt produces a gush of melt water through the river systems.

West of Kaktovik, Barter Is.

End of the Line *N 70 8.054 W 143 38.807*

August 3, 2012

The Village of Kaktovik is located on Barter Island in the eastern Beaufort Sea. Here a snow fence is seen collapsing into the Beaufort Sea as a result of rapid coastal erosion. Blocks of tundra slither down the cliff face onto the beach. The permafrost cliff is made up of a combination of fine sediment and ice, leaving little material on the beach as they erode and are whisked away by the waves. Elders from the village remember walking up and down these cliffs and walking along the beach – an activity that is now not possible because of the rapid erosion.

Thaw lake, Prudhoe Bay

Lines vs. Polygons *N 70 13.447 W 148 39.581*

August 5, 2012

This oil pipeline snaking along the shoreline is the perfect visual metaphor for some of the issues of the Arctic coast – an important petroleum province, a rapidly changing coastline that is hypersensitive to climate change and concerns about oil spills. This portion of the Beaufort Sea coast is very low tundra that is gradually being submerged due to melting of the permafrost (*thaw subsidence*) and rising sea level. There is not much erosion going on here – you can see the tundra polygon pattern underwater! Very little sediment is eroded as the tundra slips below sea level. At some point this pipeline will require relocation.

Between Bullen Pt. and Gordon Pt

Small View of the Bigger Picture *N 70 11.268 W 146 43.279*

August 4, 2012

This image captures the broad expanse of the North Slope coastal plain sandwiched between the Beaufort Sea and the Brooks Range to the south. The small coastal lagoon is created by this narrow barrier island closing off an embayment. There is a lot happening in this photo: storm-surge limits are defined by the log-debris piles on the tundra (left), tundra is melting and subsiding below sea level along much of the lagoon shore, tundra vegetation is affected by storm surge (brown tundra) and waves are washing sands onto the tundra to the west (right) end of the lagoon. The narrow barrier island would be completely over-washed during storm surges. The tiny inlet is maintained by current scour during spring runoff and during draining of the lagoon following storm surges.

Mary Sachs Entrance

Episodic Uniformitarianism *N 70 12.947 W 146 20.568*

August 4, 2012

Like boney fingers, the complex of spits on this island stretch to the east with the Beaufort Sea to the right and Mikkilsen Bay to the left. Each of these spits represents a sediment deposit that occurred during a single storm. Ice flows on the horizon are a reminder that for about eight to nine months of the year, the Beaufort Sea is frozen. Many of the Beaufort barrier islands are migrating landward at rates of >20 m/yr (60 ft/yr), often during storms when surges occur and storm waves move large amounts of sediment. Geologists like to refer to such processes as "*episodic uniformitarianism*" where the landscape is shaped by infrequent, high-energy events.

McClure Islands

Offshore Sculptures *N 70 23.720 W 147 31.171*

August 4, 2012

Sculpted blocks of ice are stranded on the inside of this barrier island while the pack ice is visible on the horizon. This barrier island is comprised of sand and pebble, possibly scraped from shallow nearshore by the movement of pack ice against the shore. Lines of logs delineate higher water levels that have occurred during storm surges. Logs visible near the crest of this barrier island indicate storm swash has completely submerged this island in the past.

Tigvariak Is.

All Things in One *N 70 13.790 W 147 13.219*

August 4, 2012

Log lines in the tundra reveal that conditions are not always this calm. Storm surges may exceed 3m (10 ft) and flood large areas of the tundra. In this case the logs clearly define the limit of inundation. The flooded zone also shows increased thaw lake density and alteration of vegetation due the surge. The narrow sand and gravel beach is slowly advancing over the tundra. Five sets of log line are visible on the beach, each indicating a swash limit during smaller, more frequent surges. The normal tidal range is 0.15 m (6 in) whereas winds may commonly raise or lower water levels by a meter (3 ft).

South of Cape Halkett, Harrison Bay

Rectilinear Fractures — *N 70 43.931 W 152 34.286*

August 6, 2012

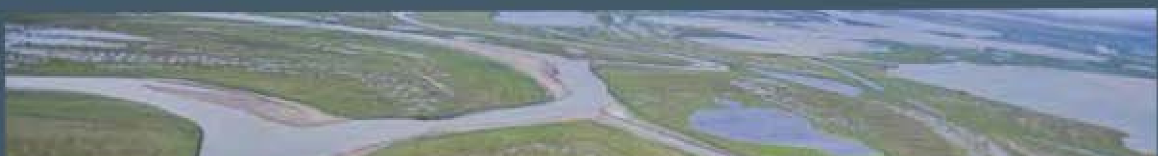
This rectilinear fracture pattern on the tundra looks as if it were scribed with a ruler. As the tundra cools during the winter it contracts, eventually cracking and producing a network of cracks in the tundra surface. During spring melt, water runs into these cracks and refreezes so that over time ice wedges build up around each crack. These ice wedges, as well as ice in the pore space of the tundra, are sensitive to melting as the relatively warm seawater laps against the shore. Near the shore (lower portion of the frame) the tundra is subsiding (*thaw subsidence*) and is gradually being inundated. Small changes in sea level can inundate substantial areas of such low-lying tundra.

Colville River Delta

A Sinuous Fabric — *N 70 22.558 W 150 53.043*

August 6, 2012

Migrating river channels in the Colville River delta weave a sinuous fabric in the tundra surface. As the river channel migrates, polygonal fracture patterns nest within the channel patterns creating this distinctive mosaic. The large channel is cutting against one bank (left), creating a 0.5 m (25 in) peat scarp while leaving a prograding sand flat on the opposite bank (right).



Between Fish Creek and Nechelik Channel, Harrison Bay

A Sinking Feeling *N70 21.854 W 151 12.923*

August 6, 2012

A disappearing landscape! Tundra that is slipping below sea level. An area of low-centered polygons where *thaw subsidence* in the polygon centers and in the polygonal fracture cracks is allowing ingress of the sea. Logs stranded on the rims of the polygons (white color) show that this entire area is submerged during storm surges. Very small changes in sea level or water level will inundate this low tundra and contribute to *thaw subsidence*.

South of Cape Halkett, Harrison Bay

Wet Reptilian Skin *N 70 39.510 W 152 29.032*

August 6, 2012

A tundra surface under duress with thaw of ice wedges along fractures and coalescence of small thaw lakes. A drained thaw lake (foreground) is showing advanced stages of thaw subsidence – almost every fracture crack is filled with standing water and more than 50% of the tundra covered in thaw lakes.

Drew Pt. Smith Bay

Thermoerosional Reality *N 70 52.965 W 153 52.766*

August 7, 2012

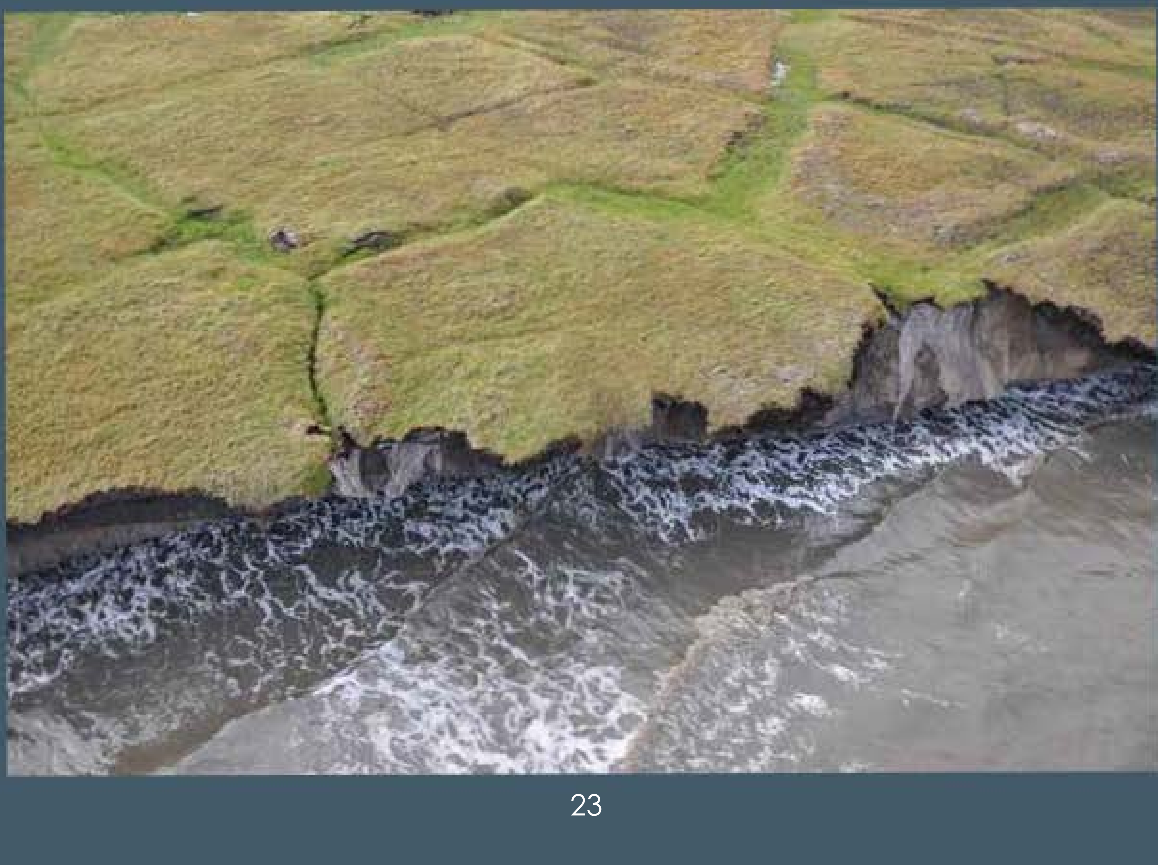
This photo shows a thaw lake near Drew Point that has been drained as the shoreline cuts across the tundra. Brown lake sediments are revealed as the lake drained through the incised channel; drainage was recent as the lake bed is still unvegetated and no post-draining fracture pattern has developed. The vertical cliff face is indicative of rapid erosion – note the notch cut into the base of the cliff by the wave action. At some locations this notch (a thermoerosional niche) may extend as much as 10 m (30 ft) into the cliff but the permafrost supports the overhang. Where the notch reaches a weakness, such as the polygonal fracture crack, a large block breaks off (right). Note the ice wedges in the cliff face. Because the sediments are fine (clays and silts) and contain a large amount of ice, no sediment accumulates on the beach. Documented erosion near this site is 30 m/yr (100 ft/yr). Beach dams may be partially or completely destroyed.

Drew Pt. Smith Bay

Sweeping Under the Carpet *N 70 22.558 W 150 53.043*

August 7, 2012

A dramatic sea cliff on the Beaufort Sea coast which is being undercut by waves. The niche at the base of the cliff is melted into the permafrost and may extend as much as 10 m (30 ft). Note the ice wedges in the cliff face where the fracture pattern intersects the shore. Eventually a large block will break off and tumble into the sea. Note the complete lack of a beach – much of the eroded material is ice and the remainder is fine sediment that is whisked away by the waves.



West of Tangent Pt., Dease Inlet, Elson Lagoon

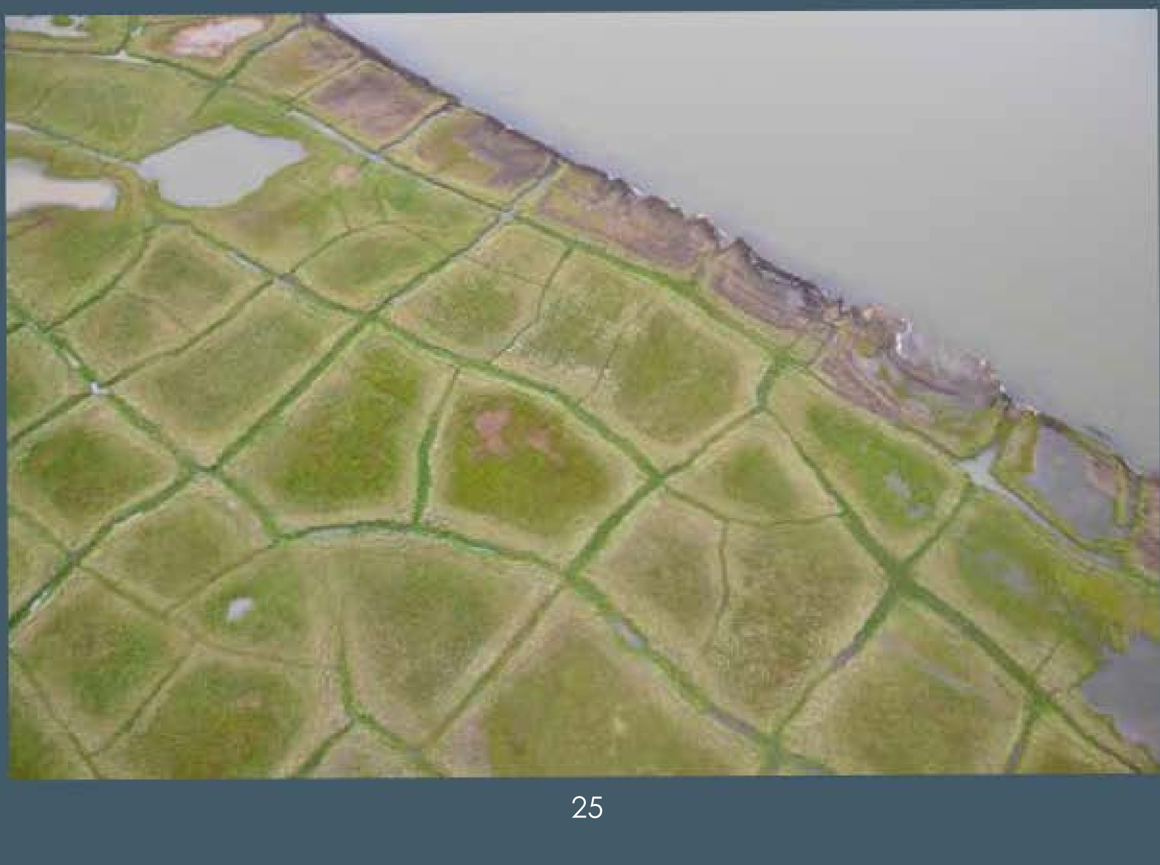
Natural Fresco *N 71 5.427 W 155 11.818*
August 7, 2012

A palette of greens and browns accentuate small elevation differences on this tundra remnant while the waves of Dease Inlet consume the shoreline. A reedy brown vegetation in the low-centered polygons grades through a series of greens and then to almost a white on the polygon crests. This site is sensitive to flooding from storm surges or sea level change because of the low elevation.

Entrance to Pittalukruak Lake, Admiralty Bay

Vascular Tundra *N 60 17.815, W 147 12.431*
August 10, 2012

The polygonal fracture pattern of the tundra abruptly ends at the lagoon edge (Admiralty Bay). Near the shore, flooding has altered the tundra vegetation (brown coloration) and caused *thaw subsidence* such that the tundra surface is sinking below sea level. Erosion of the tundra peat layer has caused peat to be redistributed along the shore .



Piasuk River Delta, Smith Bay

Polygon Mosaic *N 70 51. 024 W 154 39.150*

August 7, 2012

This patch of tundra is sandwiched between Smith Bay and a large lake. The melting of ice wedges that are beneath each fracture crack are evident near the shore creating fingers like a small canals stretching into the tundra. The tundra vegetation has been killed (brown near the shore) in areas that have been more frequently flooded. This type of shoreline would be worrisome during an oil spill as oil reaching into the fingers would be hard to recover. Note the two small flocks of eider chicks at lower right.

Black Pt., Dease Inlet

A Leathery Skin *N 71 4.678 W 155 15.273*

August 7, 2012

This tundra peninsula lies between a thaw lake (background) and Dease Inlet (foreground). Note the transition from high-centered polygons on the left and the low-centered polygons on the right. The tundra surface is about 1 m (3 ft) above sea level and shows no evidence of being flooded (no stranded logs or damaged vegetation). The substrate is likely mostly peat and ice is melting away, leaving drape of tundra vegetation over the low scarp. The shallowness of the nearshore is evident as waves are breaking well offshore in this photo.

Skull Cliffs

Erosional Resistance *N 70 56.724 W 157 31.089*

August 9, 2012

Skull Cliffs to the south of Barrow is one of the only places on the North Slope where bedrock occurs. The base of these cliffs is a cemented sandstone that resists erosion such as might occur on stormy day like this one. Sea caves have been cut into the sandstone and there are cobble beaches (right) that are very rare along the North Slope. These cliffs are about 10 m (30 ft).

Kuk River, Wainwright Inlet

River Meets Permafrost *N 70 13.951 W 159 49.873*

August 12, 2012

A complex area of channels in Kuk River on the Chukchi coast. Even though wave energies are extremely low in these lagoons, shorelines are still undergoing erosion, like the shores of these channels. Low, bushy willows (on the rim of the thaw lake at lower left and across the channel) are more common along the Chukchi, especially on unstable slopes.

South of Agiak Pt., Kuk River, Wainwright Inlet

A Stormy Path *N 70 27.854 W 159 54.285*

August 11, 2012

Beach ridges on a cuspate point in Wainwright Inlet create a record of a prograding shoreline. Each ridge probably represents a sediment deposit from a storm event. During a storm, sediment would be eroded from cliffs (left edge of photo), transported along the shore and deposited as a distinct ridge. The ridges have been truncated by erosion along the bottom shore and sediment carried off into the lagoon (at left). The subtle differences in colors of the ridges reflect slight elevation differences where the crests of the ridges are lighter and the troughs are slightly darker.

Kuk River, Wainwright Inlet

Fringing Transparency *N 70 14.044 W 159 48.100*

August 12, 2012

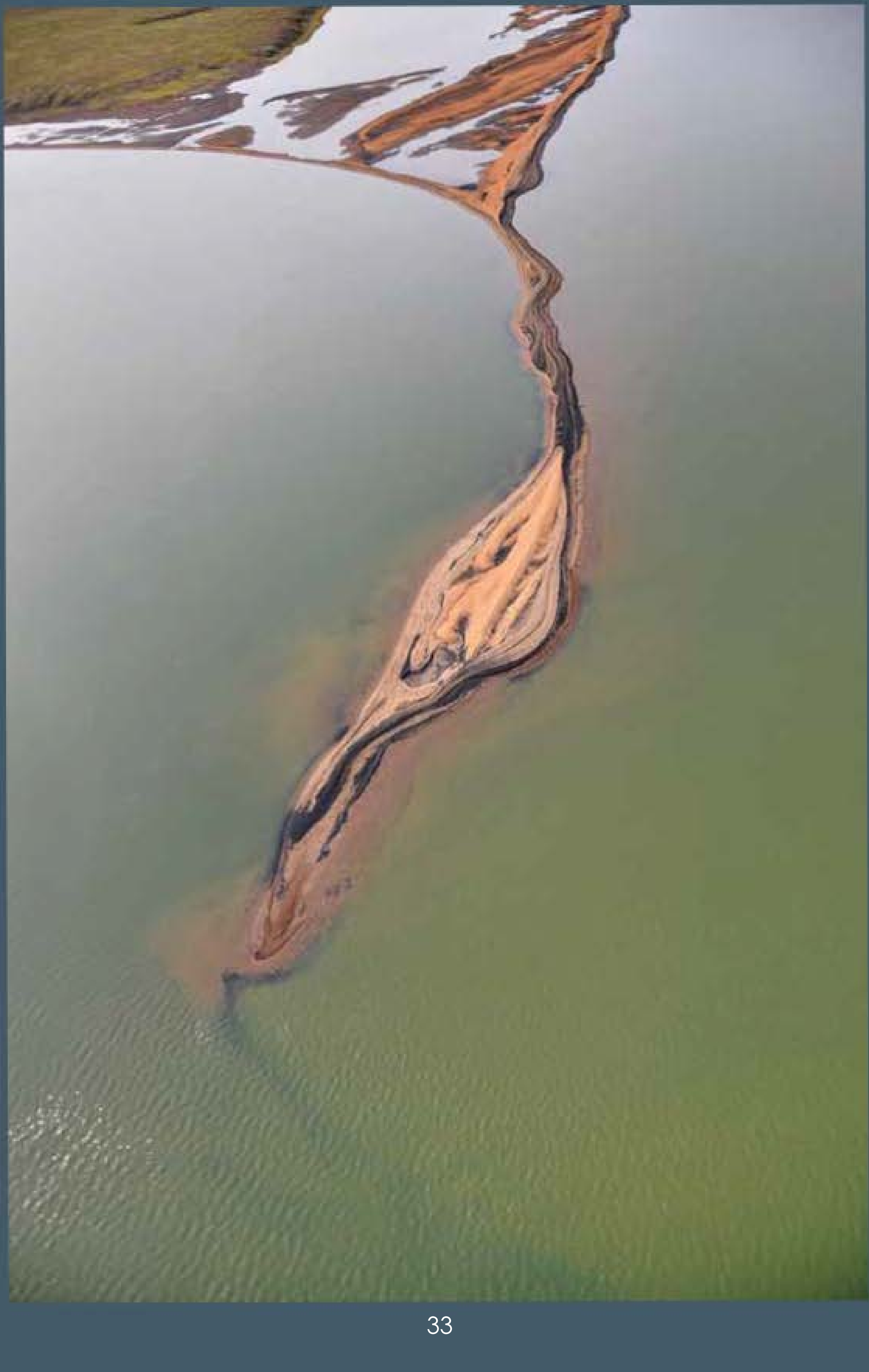
A small fringing marsh at the base of a tundra slope. There is a narrow sand beach (~1 m or ~3 ft wide) and then a very shallow flat in the subtidal. The dark shading on the tidal flat is likely the accumulation of peat detritus that collects in shallow troughs. This entire marsh would be flooded during a storm surge.

Entrance to Kungok River, Wainwright Inlet

Diving Seabird *N 70 29.414 W 159 44.595*

August 11, 2012

A finger reaches out from the shore in Wainwright Inlet. The finger is a convergence zone of sediment transport where two arms of the lagoon meet with wave transporting sediment to the point from different directions. There are eroding coal beds in the Inlet that contribute the black coloration. Like many of the areas on the North Slope, major sediment transport events occur during storms so the landscape exudes this "pulse" morphology.



Kasegaluk Lagoon, Pt. Lay

A Clear Path *N 69 43.736 W 163 3.890*

August 12, 2012

The low cloud and the glassy sea swallow the horizon in this image of the ruler-straight barrier island on the outer shore of Kasegulak Lagoon, which stretches 185 km (115 mi) along the Chukchi sea coast. The Kasegulak Lagoon is typically about 5 km (3 mi) in width but mostly a few meters (<6 ft) deep. The barrier island is one of the longest barrier island systems in North America.

Akunik Pass, Kasegaluk Lagoon

Enter Now, Not Later *N 69 54.376 W 162 49.482*

August 12, 2012

Akunik Pass south of Icy Cape shows the pulses of sediment transport in the form of recurved spits that are produced by alongshore sediment transport during storms. The band of shoals inside the inlet are part of a tidal delta that forms from currents flooding through the inlet (*flood tidal delta*). As this inlet has migrated along the coast (from south to north, right to left), the flood tidal deltas are left as an elongate shoal. These barrier islands wash completely over during storm surges.

North of Kilimantavi

Nature's Highway *N 70 30.028 W 160 22.114*

August 13, 2012

The northern end of the Kaselgulak Lagoon system with Wainwright Inlet in the background (upper right). The pebbly sand barrier islands to the left contrast with the lush green wetland shores of the lagoon. The outer coast can experience large storm waves whereas as the lagoons are relatively protected from large waves, allowing extensive marshes to develop. These barrier islands extend for nearly 200 km (125 mi) to the south from Wainwright.

South of Noakok Pass, Kasegaluk Lagoon

Enter Later *N 69 25.989 W 163 9.313*
August 17, 2012

The southern portion of the Kasegulak Lagoon is incredibly linear barrier island system (Naokok Pass). Surf lines, apparent when this photo was taken, show that there are offshore bars that attach to the shoreline and that a tidal delta is present on the seaward side of the inlet, formed by currents ebbing from the lagoon (*ebb-tidal delta*). Washover fans, formed by wave washing over the barrier islands, are smoothed by lagoon waves.

South of Wainwright

Biophysical Paradox *N 70 28.095 W 160 27.966*

August 13, 2012

A birds-eye view of the across-shore morphology on a barrier island along the Chukchi coast. The wave-dominated beach face dominates the outer shore and during storms, waves wash completely across the barrier island. The *washover fans* on the landward side of the barrier island are largely devoid of vegetation. At this location, only a very narrow lagoon is present giving way to salt marshes. These lagoon marshes are important bird habitats and juvenile fish rearing areas.

Inside Icy Cape Pass, Kasegaluk Lagoon

Relict Relief *N 70 15.848 W 162 4.684*

August 13, 2012

Slight differences in sediment texture create arcuate swirls in this image, which looks from the lagoon out to the Chukchi Sea near Icy Cape. The channel is a relict inlet that has been closed by alongshore sediment transport. Three subtle curves (center and upper right) mark recurved spits that were formed when the inlet was open; their morphology indicates sediment transport from left to right. The beach complex at lower left was formed by lagoon waves, again pushing sediment from left to right. The darkest areas are a pebbly veneer over sand. The lightest colored areas are sand and the swales between the recurved spits are wetted sand and mud (lighter brown color).


Russia
Chukchi Sea
Kotzebue Sound
Norton Sound
Bering Sea

Arctic Ocean
Beaufort Sea
Kotzebue
Point Hope
Barrow
Prudhoe Bay
Kaktovik
Alaska
N
750 375 0 750
Miles

Just south of Noakok Pass, Kasegaluk Lagoon

Swashing Overwash *N 69 27.129 W 163 8.806*

August 16, 2012

A major storm was occurring as this photo was taken along the barrier island at the southern end of Kasegulak Lagoon. This is the type of event that significantly alters morphology along the coast. The breaking waves highlight an offshore bar and the wave direction from the southwest is driving alongshore sediment transport towards the lower part of the photo. Waves can be seen washing over a berm in the lower part of the photo, probably where an offshore bar attached to the beach. Swash in the centre portion of the photo is very close to over topping the barrier island. Meanwhile, the short fetch within lagoon limits wave development and a relative calm prevails there.

Agiak Lagoon

White Veined Watershed *N 68 54.769 W 164 29.793*

August 16, 2012

A small valley opens on to Agiak Lagoon near Cape Sabine where a small delta has formed. Longshore sediment transport has moved sand to the west (left to right), as evidenced by several sediment lobes just to the right of the stream mouth. In spite of the local sediment source, shorelines both to the left and right of the stream are actively eroding. The white highlights in the upland is Cotton grass growing in the moist drainages.

Cape Dyer, Lisburne Peninsula

Brooks Range Drama *N 68 45.335 W 166 12.302*

August 18, 2012

The Brooks Range touches the coast at Cape Lisburne, one of the defining headlands in the Arctic. Bedrock cliffs shed talus into the Chukchi while a small stream provides coarse sediment to small pocket beaches to the south. Thousands of seabirds nest on these cliffs and feed in adjacent waters.

North of Cape Sabine

Melting, Slumping, Oozing *N 68 59.773 W 163 55.631*

August 17, 2012

Ground ice slumps near Cape Beaufort on the Chukchi Sea coast indicate very high ice contents in the surface sediments of the tundra. High wave energy removes the oozing sediment from the toes of the slumps.

Point Hope

Oh, That Point *N 68 20.261 W 166 50.685*

July 21, 2012

Turning the corner at Point Hope – one of the great convergence zones on the coast. Longshore sediment transport from the north and from the south meet at Pt Hope forming this continental-scale cuspate foreland. Beaches here have been prograding over thousands of years and human occupation at the Point has followed this progradation seaward. The village of Point Hope is visible in the distance. Beaches of pebble stretch uninterrupted 30 km (20 mi) to the north and 230 km (145 mi) south to Kotzebue.

Imnakpak Cliffs, Cape Thompson

Can you Sea Caves *N 68 8.600 W 165 59.644*

July 22, 2012

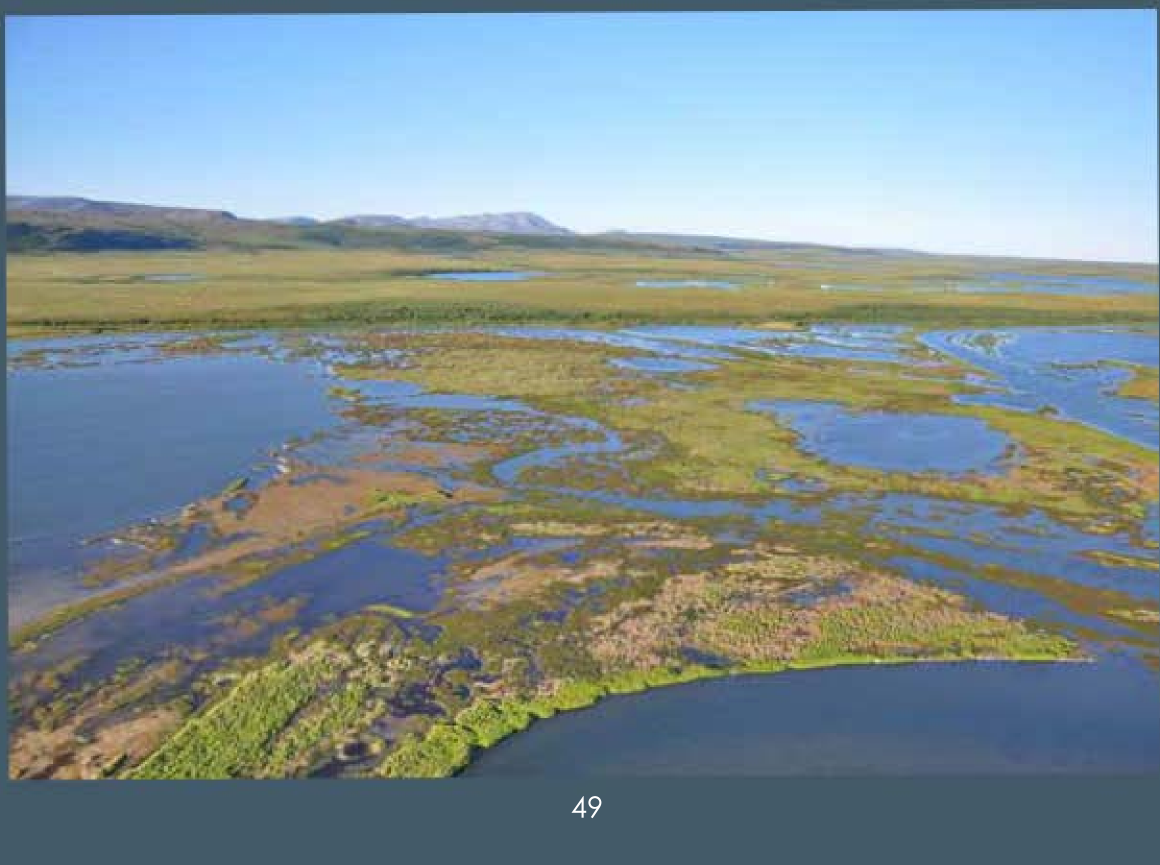
Pt. Thompson south of Pt. Hope is one of the few bedrock headlands in the southern Chukchi Sea. The vertical rock cliffs offer a stark contrast to the more subdued, rounded landscape further inland.

Krusenstern Lagoon, Cape Krusenstern National Monument

Smorgasbord of Features *N 67 6.696 W 163 27.265*

July 22, 2012

This image captures a smorgasbord of landforms from the mountain range in the background easing into a coastal plain and then a complex lagoon marsh system. The marsh morphology at upper right is built around a relict river channel whereas the marsh left foreground is superimposed around a relict beach ridge system. Marshes are one of the most common shore types in the Kotzebue Sound coastal region.



Cape Krusenstern National Monument, Kotzebue Sound

Thousand year Growth *N 67 5.706 W 163 36.910*

July 22, 2012

These linear beach ridges near Cape Krusenstern National Monument mark a beach system that has grown seaward over thousands of years. Like other parts of the Alaskan arctic, the beach ridges indicate a pulsing system where each ridge can be related to a storm and subsequent recovery period. There is no obvious sand source for this wide beach ridge plain so the source is probably the shallow offshore where wave processes create a gradual onshore migration of sediment.

Kotlik Lagoon, Cape Krusenstern National Monument

Pebbly Bas Relief *N 67 22.383 W 163 48.247*

July 22, 2012

Pebble-cobble berms enclose this small lagoon in Kotlik Lagoon. There are berms piled upon berms and these are juxtaposed to a delicate marsh system behind the berms and a muddy tundra cliff that is eroding (to right). The pebble-cobble sediment source is to the left with sediment transport from left to right.

Holtham Inlet, Kotzebue Sound

Green Stalagmites *N 67 2.872 W 161 49.791*

July 22, 2012

This image looks almost pastoral as the coastal plain slopes down to the brackish waters of Holtham Inlet near the entrance to Selawik Lake. Spruce trees line old, relict shorelines along the backshore and brackish water marsh extends into the Lake. Low shrubs extend right to the shore and have been killed (white coloration) by either ice or salt water. Seagrass is visible in the shallow subtidal.

Choris Peninsula, Kotzebue Sound

Crab Claw *N 66 16.020 W 161 54.520*

July 21, 2012

One of the few rock outcrops in Kotzebue Sound, near the south end of the Choris Peninsula. The bedrock is resistant to erosion and stands as near vertical rock cliffs.

Ekichuk Lake, Kotzebue Sound

Filtration *N 66 35.836 W 160 19.307*

July 22, 2012

Ekichuk Lake shows intricate marsh patterns in the delta. Very slight changes in elevation (a few centimeters or inches) control the vegetation complex. Low willow-type shrubs rim the channel. Darker areas represent the more stable tundra at slightly higher elevation.

Eschscholtz Bay, Baldwin Peninsula, Kotzebue Sound

Willow Hollow *N 66 21.722 W 161 17.360*

July 21, 2012

There is more than meets the eye in this image of a barrier spit, narrow lagoon and vegetated cliff. Updrift (to the left and out of view), a stream reaches the coast and has been pinned along the shore by the barrier island. As the barrier spit has grown (from left to right), it protects the cliffs from direct wave erosion and the cliffs have become partially stabilized. A small inlet that probably developed during spring freshet, has been filled by alongshore sediment transport. A permanent inlet exists downdrift (to the right). Although the cliff is vegetated with low willow shrubs, blocks of tundra are still moving down the cliff face and the toe of this slump is colonized by marsh (bright green) and dune grasses (dusty green).

Singauruk Point, Selawik Lake, Kotzebue Sound

Pulsing Progradiation *N 66 34.912 W 160 30.166*

July 22, 2012

Beach ridges and recurved spits at Singauruk Spit show a long history of progradation from the top to the lower portion of the photo. As the spit has been prograding to east (top to bottom) it has also been eroding so that portions of the older recurved spits have been truncated. Each recurve is likely related to a single storm event, when storm waves would erode, transport and deposit a large pulse of sediment.

Eschscholtz Bay, southern Kotzebue Sound

Show-it-all Spit *N 66 16.451 W 161 50.457*

July 21, 2013

A recurved spit jutting out from the shoreline into Eschscholtz Bay, southern Kotzebue Sound. This image shows it all – the eroding shoreline (sediment source), the skinny barrier spit (sediment transport zone) and the recurved spits (depositional zone). One can tell that the entire spit is migrating (left to right) as the older recurved spits have been truncated. There are more than 15 sediment pulses (recurved spits) visible with each likely the result of a storm-wave deposit.

Baldwin Peninsula, southern Kotzebue Sound

Saw-tooth Decay *N 66 39.365 W 162 7.938*

July 21, 2012

The saw-tooth morphology of these eroding tundra cliffs on the Baldwin Peninsula is relatively common in southern Kotzebue Sound. The presence of willows is an indicator that these cliffs are south of Point Hope. The "gullies" between the teeth were likely locations where ice wedges beneath the polygonal fractures of the permafrost melted. Now these gullies carry sediment wash, seen as a small fan on the beach (left), and slumps (to right). There is not much coarse material in these cliffs, so there is no protective beach forming. This beach is narrow (<10 m or 30 ft) and would be submerged during moderate storms, allowing wave to directly attack at the base of the cliff.

Kauk River Delta, Eschscholtz Bay

Nature's Levees *N 66 18.063 W 161 4.500*

July 21, 2013

Looking across the Kauk River delta (Escholtz Bay), very subtle differences in elevation are identified by color variation in the vegetation community. The dusty green coloration is dune vegetation that grows on slightly higher ground whereas the bright green salt marsh community is slightly lower and more frequently flooded. The color scheme shows how elevations are usually slightly higher next to a channel (*natural levees*) or shore. The dark brown strip along the shore is exposed peat and identifies this as an erosional shoreline where the marsh is being cut back.

Pish River, Goodhope Bay, Bering Land Bridge National Preserve

Holey Saltmarsh *N 66 11.065 W 163 57.814*

July 19, 2012

Salt marshes associated with a river delta create a bewildering array of patterns. Although the eroding sea cliffs and long barrier islands are often the coast we remember, the lagoon shores comprise the majority of the coastal length around Kotzebue Sound and salt marshes like this are the most common shore type. This particular marsh looks stable but with global warming will the density of thaw lakes (about 50% cover in this photo) increase?

Shishmaref Inlet, Bering Land Bridge National Preserve

Arcuated Accents *N 66 25.279 W 165 20.021*

July 18, 2012

Arcuate beach ridges on the barrier island near the village of Shishmaref provide a contrast to the normal straight beach ridge plains on prograding shorelines. This view, looking seaward from Shishmaref Inlet out to the Chukchi Sea shows that these barrier islands are substantially vegetated and support a marsh shoreline within the lagoon.

Cape Espenberg, Bering Land Bridge National Preserve

Wave and Wind, Give and Take *N 66 35.289 W 163 47.750*

July 19, 2012

To the east of Shishmaref, long straight beach ridges mark the progradation of the coast (from right to left). Since there are no large rivers or other visible sediment sources, it is assumed that sediments being added to the coast are from offshore. Wave dynamics cause an onshore transport of sediment on the gradual offshore slope that translates into an accreting coastline. The morphology of the more recent beach ridges (center to left) in comparison to the older ridges (to the right) suggest that the sediment transport system is slowly changing. Blow-out dunes (center) are caused by wind scouring deep pits until the base of the pit reaches permafrost or water table.

Outside Ikpek Lagoon, Bering Land Bridge National Preserve

Hummocky Dunes *N 65 58.052 W 167 4.910*

July 20, 2012

The barrier island enclosing Ikpek Lagoon to the west of Shishmaref is completely vegetated with a well-developed foredune ridge along the beach. The density of the vegetation suggests that this barrier island is highly stable and rarely washed over. The maximum astronomical tidal range is about 1 m (3 ft) but meteorological surges and wave action result in active beach zones of several meters (~ 6 ft). This beach doesn't look very different from those near Cape Hatteras in North Carolina.

Arctic Lagoon, Bering Land Bridge National Preserve

A Feathery Feature *N 65 58.442 W 166 58.673*

July 19, 2012

These recurved spits of Arctic Lagoon show how pulses of sediment over time create a large coastal feature. Even though this is a protected lagoon, infrequent storm events generate comparatively large waves that erode sediment, transport it along the shore and then deposit it into these recurved spits. Salt marsh has colonized the older ridges and is part of the extensive wetlands along this coast.

NE of Mitletukeruk, Lopp Lagoon, Bering Land Bridge National Preserve

Caribou Beach Vacation *N 65 48.813 W 167 31.150*

July 20, 2012

Lopp Lagoon – not too far from the village of Wales – looking from the tundra across a narrow portion of the lagoon to wide flats with the Chukchi Sea beyond. The flats are actually the dried inlet that connects the lagoon to the Chukchi Sea. This inlet is filled only when water levels are higher. Reindeer are grazing on this extensive area of wetland.

NE of Ah-Gude-Le Rock, Lopp Lagoon, Bering Land Bridge National Preserve

Disappearing Path *N 65 47.321 W 167 41.192*

July 20, 2012

This image looks across the wide barrier island along a channel to a large thaw lake. Present water levels are not high enough to fill the channel and alongshore transport along the open coast beach has temporarily sealed the channel. Higher water levels during storm surges would flow into the channel, and discharge during spring freshet, which occurred a few weeks prior to this photo, would be important in maintaining the channel; the channel has apparently persisted over a long time period, as the beaches have prograded seaward. The hummocky dune complex to the right of the channel is higher with a dusty-green vegetation. Elevated log lines are visible along both sides of the channel.

East of Taphook Point, Kookoolitook Lagoon

Summer Round Trip *N 63 34.814 W 171 2.604*

July 22, 2013

The inlet of Kookoolitook Lagoon looking to the west towards Gamble. The dominant wave approach from the northwest has created this elongate spit, with sediment transport from top to bottom of the image. The lagoon receives the Kookooliktook River, and the river and lagoon all link to the elongate channel in the image. The back side of the spit is vegetated with a dune grass – an indication of stability. Much of the lagoon shore to the left is salt marsh but the spit shoreline along the channel has a narrow sand beach. Breaking waves to the right indicate that a tidal delta has formed (*ebb tidal delta*) where this inlet discharges into the Bering Sea.

Vngyat Pt., north of Southwest Cape

Seabird Condos *N 63 24.708 W 171 48.233*

July 26, 2013

Rugged granitic cliffs near Vngyat Point on the west shore of St. Lawrence Island support very large seabird colonies – in excess of one million birds. The resistant bedrock cliffs are hundreds of meters high (>1,000 ft). The intertidal is bedrock with only a few accumulations of large boulders. This coast is exposed to westerlies, - a very high energy shoreline and almost impossible to access.

Near Southwest Cape

Protective Igneous *N 63 21.398 W 171 17.028*
July 24, 2013

The Powooiliak whaling camp near Southwest Cape. The point is anchored by resistant igneous bedrock with pocket beaches of gravel and sands. The high camp provides views to the south for the whalers, who hunt bowhead whales, especially during winter when a *polynya* (area of persistent open water) occurs in this area. The camp marks the western end of long sand and gravel beaches that stretch tens of kilometers (>30 mi) to the east.

Kangighsak Pt., east Tomname Lagoon

A Puzzle Piece *N 63 21.527 W 169 23.419*

July 21, 2013

A granitic bedrock headland anchors the low tundra at Kangighsak Point on the north shore of St. Lawrence Island. Log debris has been washed over the cliff edge in the distance. Small piles of logs visible on the point are hunting blinds, used in stalking seals and walrus that haul out on the beaches. Such blinds occur regularly along the shore and each blind belongs to a family.

Siknik Cape, east of Savoonga

A Stone Carpet *N 63 35.202 W 170 4.475*

July 28, 2013

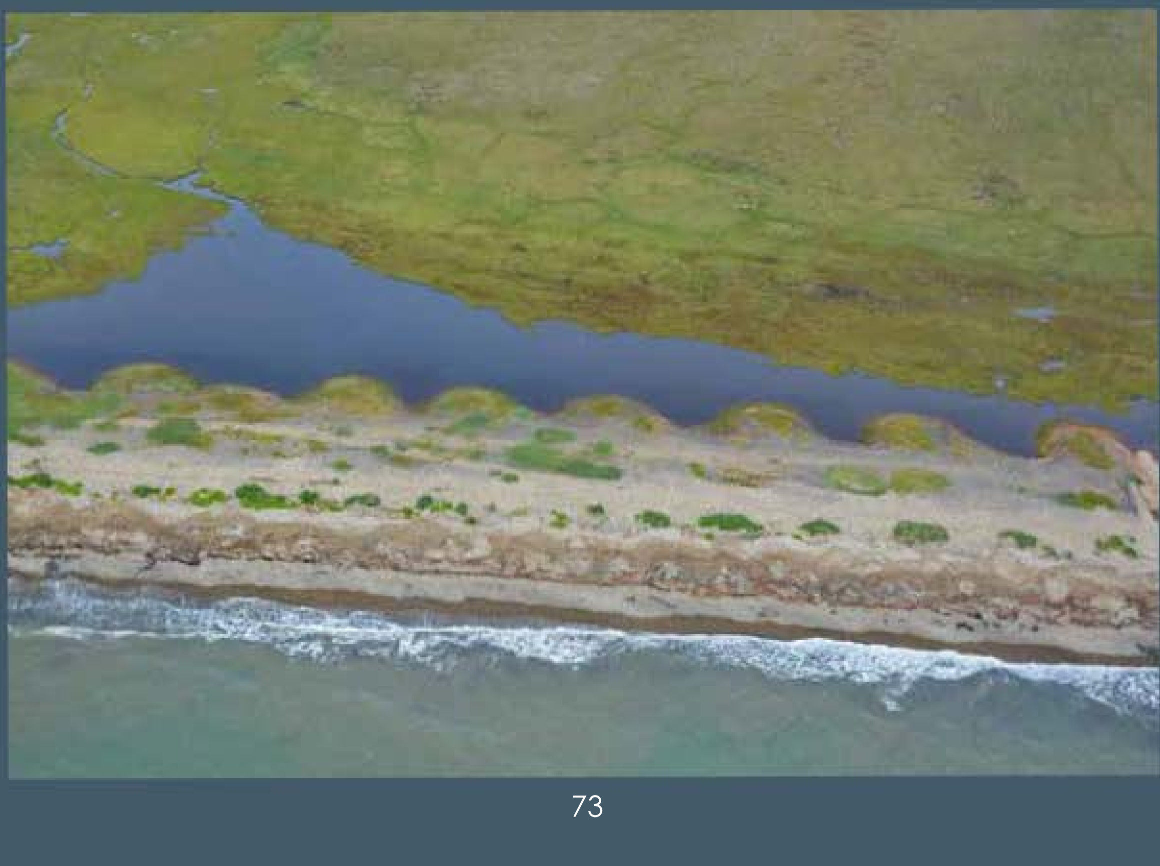
Columnar basalts crop out along the coast to the east of Savoonga on the north coast of St. Lawrence Island. The vertical cliffs (here about 20 m or 60 ft in height) are an important seabird nesting colony. The lava flows are relatively recent – within the last 15,000 years – and still present a very rugged, unweathered surface. Periglacial processes (freezing and thawing) have sorted surface boulders into a polygonal pattern with grass and other vegetation growing in the center of the sorted stone circles.

East Powooiliak Point

Crenulate Coast *N 63 23.641 W 171 12.954*

July 27, 2013

The striking rhythmic protuberances in this lagoon were likely caused by wash-over of the barrier island during a large storm. During the storm, there were locations of slightly higher water elevation that caused the wash-over fans to form. The process is similar to that process that creates beach cusps on high energy beaches. The storm that created these features likely occurred decades ago as the vegetation is well developed on the wash-over fans and on the barrier island. If one imagines walking from the outer beach (lower part of photo) across the barrier island, one would first cross bare pebble cobble, then cross an area of drift algae (the stringy black coloration is more recent and the brown may have stranded during the previous fall), and then reaching the crest of the barrier where dune grass is colonizing the pebble-cobble surface. All Terrain Vehicle (ATV) tracks (areas of slightly lighter coloration) suggest this is an important travel route. This image also provides a contrast in energies between the relatively high energy outer shore of the barrier island (lower portion of frame) and the lower energy lagoon shoreline where marsh shoreline predominates.



Human Impressions

Humans have been part of the Alaska Arctic coastline for thousands of years; and for the majority of this time they have left very little trace on the land. More recently, some of the human imprints on the landscape have been less subtle – villages consolidated around schools with permanent infrastructure, including roads, runways, schools and power generating stations. Many of these coastal communities are just a few meters (<10 ft) above sea level and very sensitive to storm surge and sea level rise. In addition, galloping rates of coastal erosion on permafrost shorelines are damaging community infrastructure. The image of Kivalina shows how this village has no place to go – shorelines are eroding on both the seaward and lagoon side of the barrier spit on which the village is located.

There are large industrial developments associated with oil exploration, and the associated pipeline corridors and support roads create a large impression on the landscape. Pipeline and road construction on permafrost require highly specialized construction techniques, and this infrastructure has the same sensitivity to coastal erosion and storm-surge inundation as occurs to the villages. At some locations, storm surges may inundate the tundra for over 5 km (3 mi) during a large event, and the structures must be designed for such hazards. Mining has also left its footprint at a few locations of Alaska's arctic shoreline (gold mining around Nome and the world's largest zinc mine at Red Dog near Kivalina). Radar stations constructed during the cold war left a trail of sites (air strips and building pads) every 80 km (50 mi) along the Alaska coast, and all of these required coastal landing sites for the annual resupply by barges.

Climate change is creating challenges for coastal communities, which derive much of their food nearby, they are intensely concerned about these changes. At every village in which the ShoreZone survey teams stopped, people asked about climate change and oil spills. Open-water is longer and storms are predicted to be more frequent and of greater intensity so the effect on coastal stability will be accelerated. Change on the coast will require humans to adapt quickly to the new conditions. Climate change has also resulted in increased arctic shipping through northern and northwest passages with associated risk of spills – where ship traffic through the Bering Straits used to involve a few dozen transits per year, there were hundreds of ship transits in 2013, including oil and LNG tankers. Offshore drilling that took place in the Chukchi and Beaufort Seas in 2012 contributes to concerns about the effect of a large oil spill on the subsistence resources of the region. With these challenges in mind, it is intriguing to visualize the likely transformation of the Alaskan Arctic coast and infrastructure over the next hundred years.

Human Impressions

Pipelines, Deadhorse

Kivalina

Red Dog Mine

Kakatovik

Biotic Impressions

Alaska's Arctic coastal zone experiences some of the most extreme environmental conditions, yet fringing vegetation such as dwarf shrubs, low turf herbs, grasses and sedges are commonly found in this zone. These species are tough, early colonizers which have evolved to tolerate subzero temperatures, low nutrient soils, acidic soils, short growing seasons, and inundation by salt and freshwater. Certain plant species specialize to dominate a specific set of conditions and can be an indicator of coastal habitat types. Dune grass is a classic example of a species commonly found in the upper spray zone of beaches and coastal dunes growing in porous, sandy substrates. This species helps stabilize mobile substrates like sand and promotes colonization by other associated species. Dune grass can form continuous, slaty green-blue stands alongshore and is classified as a dominant "bioband" by ShoreZone. Species like this are sought out for coastal habitat mapping because of their predictability in elevation and shore type.

ShoreZone has five major biobands classified in the Arctic's coastal zone: tundra, dune grass, sedges, salt marsh, and biofilms. The tundra bioband has the most diversity and is in the upper most reaches of the spray and storm surge zone, extending far inland. Tundra consists of a low turf of shrubs, herbs, grasses, sedges, mosses, and lichens which grow on top of permafrost and are not tolerant to inundation by saltwater. Dune grass biobands in the Arctic are mostly found on beach berms of barrier islands or as a narrow fringe on lagoon shorelines. Associated species found just below the dune grass are the blue colored Oyster leaf and green heads of Beach greens. Sedge biobands occur in wetlands and lagoon areas mainly influenced by freshwater in upper elevation tidal marshes. Cotton grass is one of the most striking and common sedges found in this zone. The beautiful Roseroot is often found in the lower reaches of this bioband if the area has a silty-clay soil. Salt marsh biobands are abundant in the Arctic occurring in low lying areas of protected lagoons and consisting of salt-tolerant grasses, sedges and herbs. One of the toughest species found in this zone is Alkali grass which often turns an orange-red color when it has been in saltwater. Biofilm is the most unique Arctic bioband forming a very thin organic mat on soil (cyanobacterial mat) which looks like a bright reddish-orange stain seen in many of the photos in this collection. Biofilm biobands occur in drained meltwater ponds, washover pools, and salt marsh swales.

Biota

Dune Grass

Oyster leaf

Alkali Grass

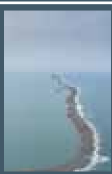
Beach Greens

Cotton Grass

Roseroot

Arctic Edge

Arctic Edge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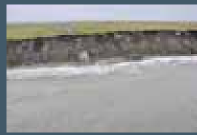
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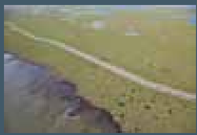
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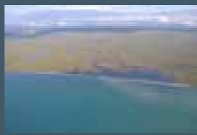
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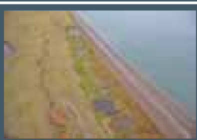
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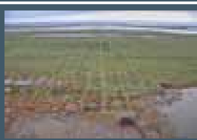
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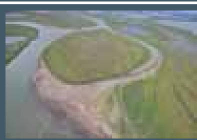
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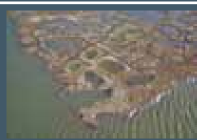
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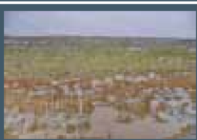
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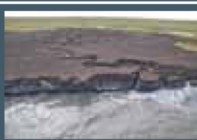
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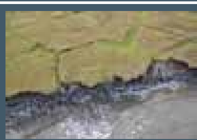
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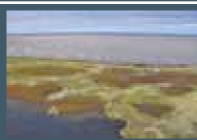
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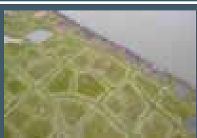
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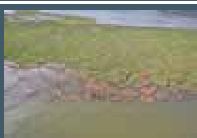
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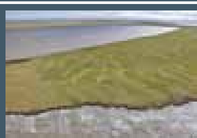
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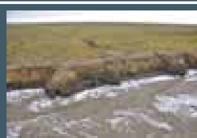
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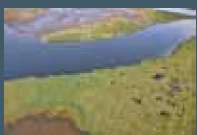
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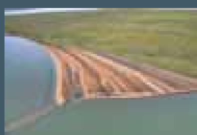
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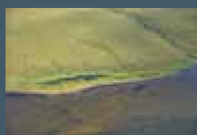
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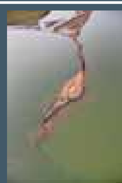
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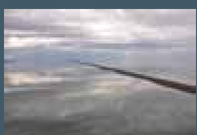
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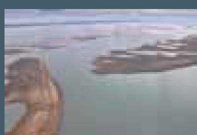
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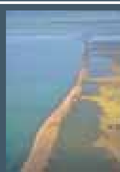
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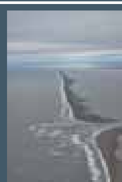
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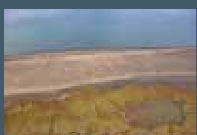
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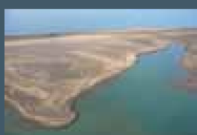
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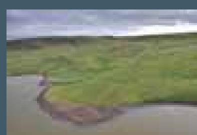
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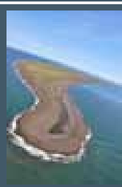
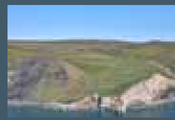
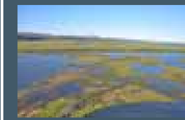
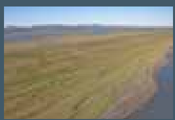
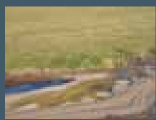
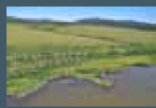
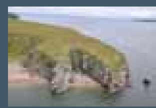
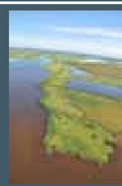
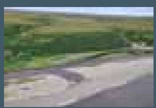
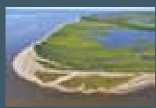
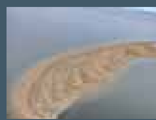
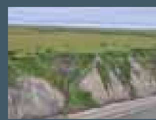
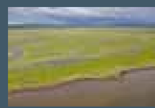
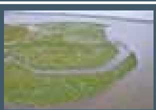
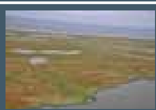
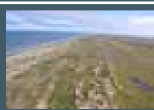
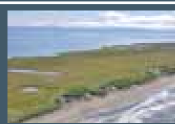
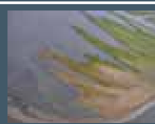
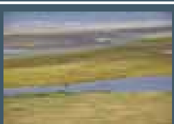
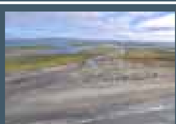
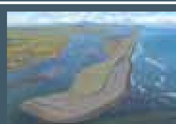
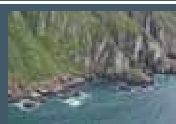
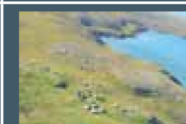
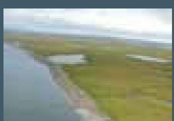
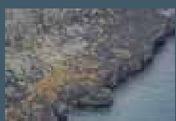
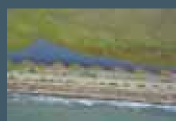
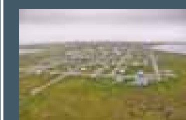
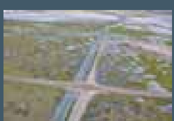
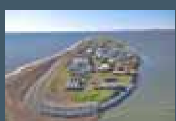
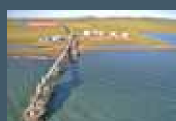
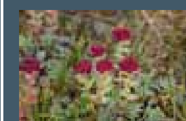
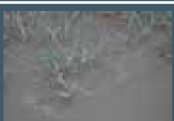
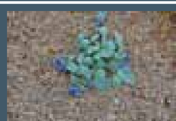
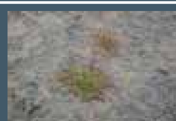
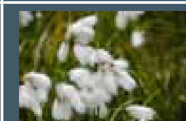
 Page 45	 Page 45	 Page 47	 Page 49	 Page 49
 Page 51	 Page 51	 Page 53	 Page 53	 Page 55
 Page 57	 Page 57	 Page 59	 Page 59	 Page 61
 Page 61	 Page 63	 Page 63	 Page 65	 Page 65
 Page 67	 Page 67	 Page 69	 Page 69	 Page 70
 Page 71	 Page 73	 Page 73	 Page 75	 Page 75
 Page 75	 Page 75	 Page 75	 Page 77	 Page 77
 Page 77	 Page 77	 Page 77	 Page 77	 Page 77