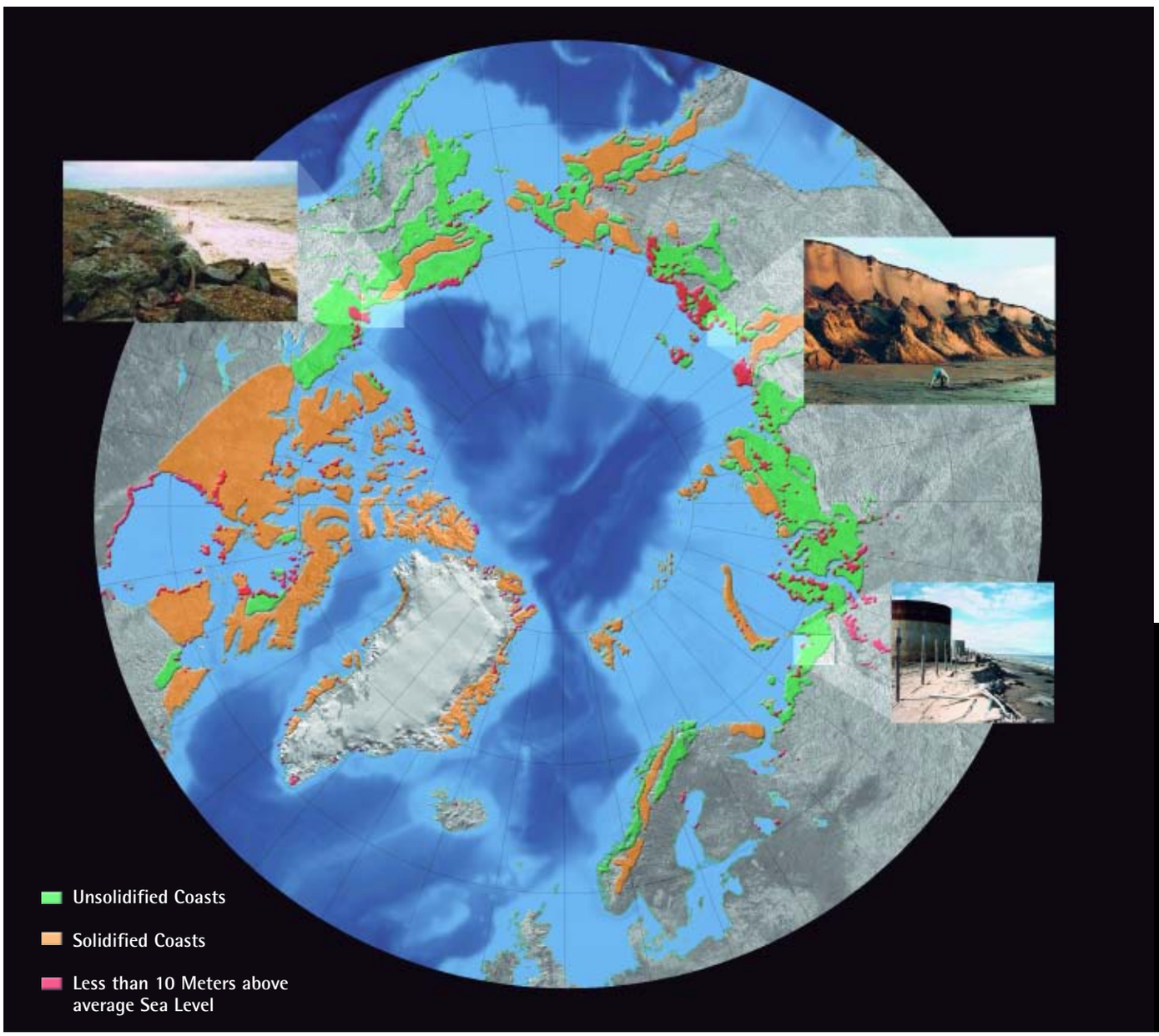
5 Many coastal communities and facilities face increasing exposure to storms.

Rising temperatures are altering the arctic coastline and much larger changes are projected to occur during this century as a result of reduced sea ice, thawing permafrost, and sea-level rise. Thinner, less extensive sea ice creates more open water, allowing stronger wave generation by winds, thus increasing wave-induced erosion along arctic shores. Sea-level rise and thawing of coastal permafrost exacerbate this problem. In some areas, an eroding shoreline combines coarse sediments with frozen seawater, creating huge blocks of ice that carry sediments for distances of over 100 kilometers. These sediment-laden ice blocks pose dangers to ships and further erode the coastline as they are carried along by the winds. Higher waves will create even greater potential for this kind of erosion damage.

"Some of our communities are eroding into the ocean in front of our eyes because of the decrease in the multi-layered ice, which is allowing for larger storms to roll in."

Duane Smith
Inuit Circumpolar Conference, Canada

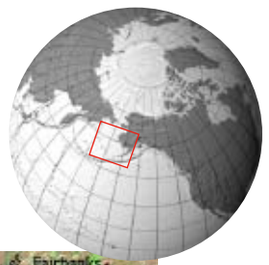
Arctic Coastal Areas Susceptible to Erosion



Rising sea level is very likely to inundate marshes and coastal plains, accelerate beach erosion, exacerbate coastal flooding, and force salt water into bays, rivers, and groundwater, not only in the Arctic, but also around the world. Local sea-level rise depends on how much the oceans are expanding as well as on whether the local coastline is rising or subsiding due to forces affecting the earth's crust (such as rebound from the last ice age). Arctic coasts show a wide variation in these trends, although low-lying coastal plains of the Arctic are generally not rising, making them more vulnerable to adverse effects of sea-level rise. Higher sea level at the mouths of rivers and bays will allow salt water to penetrate further inland. Storms that bring more intense rainfall at the coast will increase erosion by runoff and the amount of mobile sediment in coastal waters.

Coastal erosion will pose increasing problems for some ports, tanker terminals, and other industrial facilities, as well as for coastal villages.

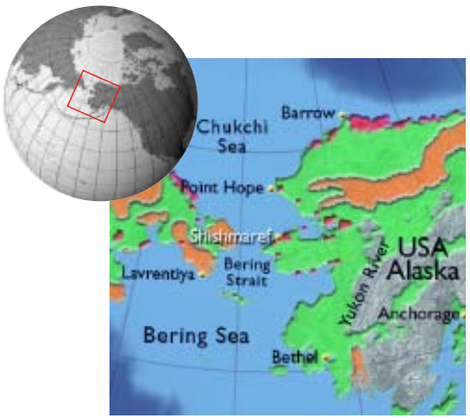
Coastal regions with underlying permafrost are especially vulnerable to erosion as ice beneath the seabed and shoreline thaws from contact with warmer air and water. Though little specific monitoring has yet been done, generally, the projected increase in air and water temperature, reduction in sea ice, and increase in height and frequency of storm surges are expected to have a destabilizing effect on coastal permafrost, resulting in increased erosion. Low-lying ice-rich permafrost coasts are thus most vulnerable to wave-induced erosion. One result of this erosion is that more sediment will be brought to coastal waters, adversely affecting marine ecosystems. Increased coastal permafrost degradation could also result in greater releases of carbon dioxide and methane. Coastal erosion will pose increasing problems for some ports, tanker terminals, and other industrial facilities, as well as for coastal villages. Some towns and industrial facilities are already suffering severe damage and some are facing relocation as warming begins to take its toll on arctic coastlines.



In the Alaskan village of Nelson Lagoon, residents have built increasingly strong break walls along the shore, only to see them destroyed by increasingly violent coastal storms. Their break walls were designed to brace the shore ice, which would in turn provide the major buffer from winter storm wave action. As winters have warmed, the buffer provided by the shore ice has been lost, allowing the full force of the waves to surge against the wall and the village. The pipeline that provides drinking water for the village was also threatened when storm waves eroded soil cover and caused a breach in the line.

The vulnerability of a coastline to erosion depends on sea level, the properties of the coastal materials, and environmental factors such as tectonic forces and wave action. Unsolidified arctic coasts (in green) containing variable amounts of ground ice, are more susceptible to erosion than solidified coasts (in orange). Unstable coastal environments are shown in the inset photographs from the Pechora, Laptev, and Beaufort Sea coasts. Tectonic forces create uplift in some places, including the Canadian Archipelago, Greenland, and Norway, and subsidence in others, such as along the Beaufort Sea and Siberian coasts. Areas (in red) in which elevation is less than 10 meters above average sea level are particularly vulnerable.

5 Many coastal communities and facilities face increasing exposure to storms.



"I went to school on the mainland, and when I came back, my house was gone. They moved it to the other side of the village, or it would've fallen in."

Leona Goodhope
Shishmaref, Alaska

Shishmaref, Alaska Faces Evacuation

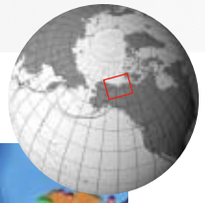
The village of Shishmaref, located on an island just off the coast of northern Alaska and inhabited for 4000 years, is now facing the prospect of evacuation. Rising temperatures are causing a reduction in sea ice and thawing of permafrost along the coast. Reduced sea ice allows higher storm surges to reach the shore and the thawing permafrost makes the shoreline more vulnerable to erosion, undermining the town's homes, water system, and other infrastructure.

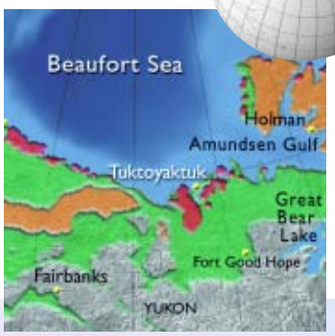
The problem of coastal erosion has become increasingly serious in Shishmaref in recent years. Over a dozen houses have already had to be moved further from the sea. The 600 residents have watched as one end of their village has been eaten away, losing as much as 15 meters of land overnight in a single storm. The absence of sea ice also deprives the residents of their means of traveling to the mainland to hunt moose and caribou, as they would normally do by early November. Nowadays, the inlet is open water in the autumn.

Village elder, Clifford Weyiouanna says, "The currents have changed, ice conditions have changed, and the freeze-up of the Chukchi Sea has really changed, too. Where we used to freeze up in the last part of October, now we don't freeze 'til around Christmas time. Under normal conditions, the sea ice out there should be four feet [1.2 meters] thick. I went out, and the ice was only one foot [0.3 meter] thick."

Over the last 40 years, villagers estimate that they have lost hundreds of square meters of land. Robert Iyatunguk, erosion coordinator for the village, explains that the retreat of the sea ice is leaving the village more vulnerable to increasingly violent weather. "The storms are getting more frequent, the winds are getting stronger, the water is getting higher, and it's noticeable to everyone in town. If we get 12-14 foot [~4-meter] waves, this place is going to get wiped out in a matter of hours. We're in panic mode because of how much ground we're losing. If our airport gets flooded out, there goes our evacuation by plane."

Severe Erosion in Tuktoyaktuk, Canada





Tuktoyaktuk is the major port in the western Canadian Arctic and the only permanent settlement on the low-lying Beaufort Sea coast. Tuktoyaktuk's location makes it highly vulnerable to increased coastal erosion due to decreased extent and duration of sea ice, accelerated thawing of permafrost, and sea-level rise. The Tuktoyaktuk Peninsula is characterized by sandy spits, barrier islands, and a series of lakes created as thawing permafrost caused the ground the collapse ("thermokarst" lakes). Erosion is already a serious problem in and around Tuktoyaktuk, threatening cultural and archeological sites and causing the abandonment of an elementary school, housing, and other buildings. Successive shoreline protection structures have been rapidly destroyed by storm surges and accompanying waves.

As warming proceeds and sea-level rise accelerates, impacts are expected to include further landward retreat of the coast, erosion of islands, more frequent flooding of low-lying areas, and breaching of freshwater thermokarst lakes and their consequent conversion into brackish or saline lagoons. The current high rates of cliff erosion are projected to increase due to higher sea levels, increased thawing of permafrost, and the increased potential for severe coastal storms during the extended open-water season. Attempts to control erosion at Tuktoyaktuk will become increasingly expensive as the surrounding coastline continues to retreat. The site could ultimately become uninhabitable.

Erosion Threatens Russian Oil Storage Facility

The oil storage facility at Varandei on the Pechora Sea was built on a barrier island. Damage to the dunes and beach due to the facility's construction and use have accelerated natural rates of coastal erosion. The Pechora Sea coasts are thought to be relatively stable, except where disturbed by human activity. Because this site has been perturbed, it is more vulnerable to damage due to storm surges and the accompanying waves that will become a growing problem as climate continues to warm. As with the other sites discussed here, the reduction in sea ice, thawing coastal permafrost, and rising sea level are projected to exacerbate the existing erosion problem. This provides an example of the potential for combined impacts of climate change and other human-caused disturbances. Sites already threatened due to human activity are often more vulnerable to the impacts of climate change.