



**National Park Service - Southwest Alaska Network**  
Inventory & Monitoring Program

Morphological Shoreline Changes along the Lake Clark National Park-Cook  
Inlet Coast, 1992-2004.

Joel Cusick  
and  
Alan Bennett

Southwest Alaska Network  
Inventory and Monitoring Program  
National Park Service  
240 West 5<sup>th</sup> Ave  
Anchorage, AK 99501



Silver Salmon - Red River Site Looking at TBM

Coastal Surveys - 2004 - LACL  
06/30/2004 1:57:49 PM

December 2005

**Recommended Citation:**

Cuscik, Joel and Alan J. Bennett, 2005. Morphological Shoreline Changes along the Lake Clark National Park-Cook Inlet Coast, 1992-2004. Southwest Alaska Network, National Park Service. Anchorage, AK. 19 Pgs.

**Topic(s):**

Monitoring, Physical, Coastal Shoreline Geomorphology

**Theme Keywords:**

Shoreline geomorphology, Beach profiles, Coastal erosion, Coastal accretion

**Place Name Keywords:**

Southwest Alaska Network, Chinitna Bay, Tuxedni Bay, Lake Clark National Park and Preserve, Cook Inlet, Gulf of Alaska

**Acronyms:**

I&M	Inventory and Monitoring
SWAN	Southwest Alaska Network
LACL	Lake Clark National Park and Preserve

**Initial Distribution:**

Southwest Alaska Network

## **Abstract**

Shoreline change was identified as a vital sign for the Southwest Alaska Monitoring Network because land loss or gain at the marine edge has important ecological and jurisdictional implications to resource managers of coastal National Parks. To evaluate the type of shoreline changes occurring along the 82 km coastline of Lake Clark National Park and Preserve, 7 of 10 cross-shore beach profiles established in 1992 were re-surveyed in 2004 using rod and transit leveling. Cross-shore beach profiles revealed variation in rates of erosion and accretion along the parks coastline. Erosion, landward migration of mean high water (MHW), was observed at 5 cross-shore profiles and accretion, seaward migration of MHW, was observed at 2 profiles. Annual average rates of erosion and accretion ranged from -0.18 to -0.50, and 0.55 to 3.13 m/yr respectively. Erosion of bluffs and shorelines has implications for protection and management of park structures, natural and cultural resources, private inholdings, and the need for future monitoring.

## **Background**

Shoreline change was identified as a vital sign for the Southwest Alaska Network (SWAN) because land loss or gain at the marine edge has important ecological and jurisdictional implications to resource managers of coastal National Parks (Bennett, et al 2005). The value of calculating the average annual rate of shoreline change is to provide an indication of likely future changes. The physical configuration of the SWAN coastal shoreline is dynamic and constantly changing due to coastal erosion and accretion from natural events, such as storm-driven waves, high tides, nearshore currents, rainfall and runoff, landslides, and earthquakes. Changes in the position of the shoreline affect the composition, relative abundance, and distribution of coastal habitats. Shoreline position also has jurisdictional implications for park management and affects cabins and other structures along the coast. Shape and sedimentary character of a beach are highly sensitive to oceanographic forcing, including deep-water wave energy, nearshore wave transformation, wave setup, storm surge, tides, and nearshore circulation. Qualitative assessments of shoreline morphology can be used as a proxy for shore-zone processes (Boak and Turner 2005).

Schoch (1996) established and surveyed 10 across-shore profiles at representative shoreline types along the Lake Clark National Park and Preserve (LACL) coastline in 1992 and 1994 using third order leveling techniques. Slope and volumetric changes and particle size distribution analyses from these shore-normal transects provided information on the sediment transport regime including erosion/accretion, rate of change, sediment sources and relative sediment abundance. To evaluate the type of shoreline changes occurring along the coastline of LACL, 7 of 10 cross-shore beach profiles established in 1992 by Schoch (1996) were resurveyed during 2004 (Figure 1).

Objectives of this project were to: 1) relocate beach profile transects to record and mark their positions using sub-meter Global Positioning Systems (GPS); 2) resample beach profiles using methods established by Schoch (1996); 3) document and interpret changes in sediment type, rates of erosion or accretion, and apply this knowledge to the development of a long-term strategy for monitoring shoreline change in SWAN.



Figure 1. Cross-shore beach profile locations, Lake Clark National Park-Cook Inlet Coastline, 2004

**Lake Clark Coastline- Physical Environment-** LACL contains 82 km (130 mi) of coastline in western lower Cook Inlet, a large tidal estuary with a length of 280 km and a width ranging from about 20 to 90 km. It is bordered on the west and northwest by the Alaska Range, on the northeast by the Talkeetna Mountains, and on the southeast by the Kenai-Chugach Mountains. Cook Inlet is an extremely dynamic, high-energy estuarine environment. The tides in the inlet are characterized by two highs and lows of unequal height in each period of approximately 25 hours (Dames and Moore, 1978). The normal tidal cycle, completed in just over 12 hours, has an average height ranging from about 5.5 m in Kachemak Bay to 8.8 m at Anchorage. Extreme high tides can be in excess of 11 m, making the tidal ranges in Cook Inlet among the largest in the world.

The rivers emptying into Cook Inlet carry very high loads of suspended sediments, mainly fine glacial flour. The high tidal currents and turbulent mixing of the waters of the inlet prevent most of these suspended sediments from settling to the bottom. As a result, concentrations of suspended sediments in the waters of Western Cook Inlet are very high. Average concentrations of suspended sediments are about 200 mg/l with maximum concentrations in excess of 2,000 mg/l (Feely and Massoth 1982). Fine-grained sediments are carried south through the lower Inlet and into Shelikof Strait and the outer continental shelf of the Gulf of Alaska. Schoch (1996) suggests that sediment transport direction along the LACL shoreline is generally southwest with counterclockwise transport in Tuxedni and Chinitna Bays.

Forty-three percent of the LACL coastline is either very protected or protected from high energy waves (Schoch 1996). Over half of this length includes the salt marshes of Tuxedni and Chinitna Bays. No portions of the LACL shoreline are fully exposed to the wave climate of the Gulf of Alaska, however, southeast storm swells from the Gulf penetrate into Lower Cook Inlet during the winter months. These events cause very large berms to develop on boulder beaches in the semi-exposed regions.

Salt marsh accounts for 22% of the total shoreline length and 42% of the total intertidal area. The combined soft substrates (saltmarsh, sand and mud flats) account for 90% of the total length and 98% of the total area (Schoch 1996). Combinations of rocky shores (ramps, platforms, cliffs) are a very small percentage of the total habitat type on the LACL coastline. Major freshwater streams are the Tuxedni River, Crescent River, West Glacier Creek, Red River, Johnson River, Silver Salmon Creek, and Shelter Creek. Several miles of the lower portions of the Tuxedni River, Johnson River and West Glacier Creek are tidally influenced.

Most sediment found in beaches, mud flats, and tidal marshes along the LACL coastline is the result of upland erosion. Glacial streams that flow into the headwaters of the bays and deltas along the outer coast contribute fine material that may eventually make its way to the open coast, but by far the largest volume of coastal and beach sediment is derived from the recession of bluffs along Cook Inlet which are comprised mainly of glacial deposits.

## **Methods:**

***Relocation and surveying-*** The beach component of the nearshore environment is defined as the profile of the shore in which sediment is moved by wave forces. This area extends from the beach toe (foreshore) to the bluff (backshore) and includes the limit of the high water storm surge which is often defined by a berm, mean high water (MHW), the beach face, the low-tide terrace, and an offshore zone (Figure 2). Though the bluff may contribute to the beach from time to time, it lies landward of the

backshore and is not part of the beach in this definition. The offshore zone is the seaward portion of the beach profile to a depth below which waves no longer affect the bottom sediment. The beach width is measured perpendicular to the shoreline, from the deepest depth where the most extreme waves cease to cause sediment movement to the landward limit of wave run-up.

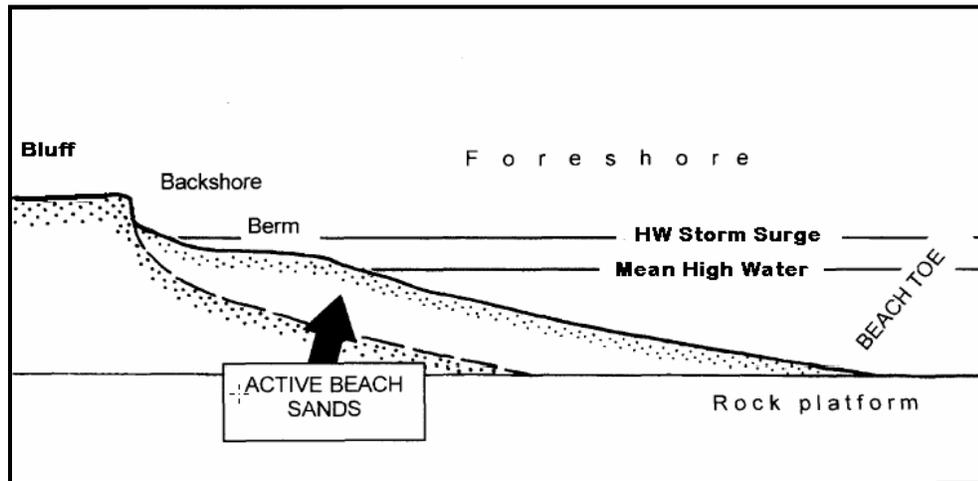


Figure 2. Simplified depiction of the beach features that were measured with cross-shore beach profiles.

Beach profiles were visited by boat (Slope Mountain), foot (Red River) and helicopter (Glacier Spit, Clam Point, Spring Point, Polly Creek, Crescent River). Site visits were timed to coincide with low tidal windows. A metal detector was used to assist in finding the 4' rebar temporary bench mark (TMB) placed at ground level in the backshore in 1992. Aluminum caps on the TMB's were assessed for damage and replaced if necessary. Once the TMB was recovered, standard direct leveling (profile leveling) techniques were used with an autolevel (NIKON Inc.) set on an aluminum tripod and leveled horizontally using a level bubble. Level rod shots were then recorded to the nearest tenth foot ( $\pm 0.1$ ) along the tape, beginning at the zero end (0 at TMB) and ending at waterline. Tape was draped over substrate, therefore true horizontal distances cannot be calculated. Major elevation "breaks" were collected by placing a leveling rod (in tenths of feet) at tape increments (to the nearest tenth of foot) and the height of that position recorded using the tripod mounted level. In order to replicate previous surveys, distances along tape were re-recorded and then any new breaks were collected if time permitted. Transects were completed to waterline and the time recorded.

Each profile survey began and ended with a close-out to the nearest tenth of a foot using the TMB as the first turning point and turning point located somewhere along the transect. Some transects required that the level be moved to ensure rod visibility. In these cases, two turning points were established and the transect was closed out to the nearest tenth of a foot. Data was recorded in a Rite in Rain® notebook following

standard leveling form. Printouts of original profile Excel spreadsheets were available for replicating tape distance measurements. English units of measurement, used by Schoch (1996) and customary for land survey's, have been retained for plotting beach profiles.

Documentation of each site included collecting multiple digital photos of TBM, tape placement and beach overviews using GPSPhotolink ([www.geospatialexperts.com](http://www.geospatialexperts.com)) and a handheld Garmin Map76 (Garmin GPS) to establish coarse GPS coordinates of each photograph. Coordinates displayed on photos are in NAD27 Alaska Datum for ease of navigation with handheld GPS units set to AlaskaNAD27. Garmin data is not intended for high precision or accurate navigation. In order to establish more accurate positions of each recovered TBM and profile transect, a Trimble Pathfinder Pro XR and GeoExplorer XT GPS receivers (single frequency, L1, code phase) were used to collect data at GPS quality filters to allow maximum data collection (PDOP mask 90, SNR 6, Elevation Mask 15 degrees). TBM's were recorded for a minimum of 20 minutes at 5 second logging interval by placing the GPS unit above aluminum cap and with a clear view of the sky. Transects were recorded as line features between the zero end (TBM) and waterline. Data was collected in SSF Trimble format, and checked in the field using Trimble's Pathfinder Office (v. 3.0).

During the survey, notation was made of the width of the dry beach, position of the mean water line, the high water line (or the base of the beach where well defined). Changes were documented in substrate type, position of foreshore and backshore vegetation, and position of top and toe of the bluff.

***Data recording and analysis-*** All GPS data was downloaded into Pathfinder Office (v. 3.0) and differentially corrected with Kenai CORS (baseline 98km). Corrected GPS data was exported in ESRI Shapefile format (Decimal Degree, NADCON Alaska Datum, Geoid 99, feet above MSL). Shapefiles were QC'd and processed ArcGIS (v. 8.3). All transect line data was snapped to TBM locations since longer occupation on these points will be of higher quality than the instantaneous position along the line. TBM points and line were converted to coverages and joined into multi-feature coverage called "la04bptr". GIS Data was submitted with FGDC metadata to the NPS Alaska Permanent Dataset and can be found in the LACL themelist as "2004 Recovered Beach Profile Transects" and "2004 Recovered Beach Profile TBM's". Hyperlinks (ArcView hotlinks) were established to provide GIS access to digital photos taken on site.

Profile data was transcribed into copies of the 1992-94 Excel spreadsheets created by Schoch (1996) and calibrated to the heights above MLLW as determined by Schoch using tidal station data from Snug Harbor (Table 1). Once elevations were calibrated to site TBM elevations, graphical depictions of the 2004 profiles were then added to existing graphs for comparison. Comparisons of horizontal shoreline change between 1992-94 and 2004 in all cross-shore profiles are measured against the position of MHW. In some cases, data supported comparisons in the horizontal position of the HW storm

berm and bluff edge. Other data comparisons involve vertical changes in the profile at MHW or between the backshore and the beach toe.

**Table 1.** Elevations of temporary bench marks (TBM) for each site. Units in meters above MLLW as calculated by a Tidal program for Snug Harbor (Schoch CD, 1996)

<i><b>SITE</b></i>	<i><b>Elevation (meters above MLLW)</b></i>
SLOPE MOUNTAIN	8.56
RED RIVER (SILVER SALMON)	7.04
POLLY CREEK	12.30
GLACIER SPIT	7.40
CLAM POINT	9.41
SPRING POINT	7.08
CRESCENT RIVER	10.74

### **Results and Discussion:**

Seven cross-shore profile sites were surveyed in July, 2004. All of these sites had been previously surveyed in both 1992 and 1994 (Schoch 1996) and were situated along medium to high energy shorelines. Three low energy beach profile sites located within Tuxedni Bay that were surveyed only in 1992 were not visited in 2004 (Figure 2). Once on site, recovery of the TBM's sometimes took from 20 minutes to 2 hours due to thick vegetation, low quality photo scans, or lack of reliable GPS positions. A metal detector proved crucial in relocating the rebar. TBM's most easily located were those placed near an object that was visible on the aerial photos, and not placed near thick vegetation, storm berms, or erosion escarpments.

GPS data was collected from TBM's at each beach profile. Although no on-site accuracy measurements were made for GPS positions, long occupation times and the investigators previous experience with this equipment probably resulted in sub-meter horizontal accuracies. Some elevation breaks previously recorded (e.g. top of log) were not possible to replicate since the object had either moved or the object was buried. Ground measurements, field notes, and photographs were collected to produce detailed maps of each site (Appendix A).

Cross-shore beach profiles revealed variation in rates of erosion and accretion across the Lake Clark Coastline between 1992 and 2004 (Figures 3). Erosion (landward migration of MHW) was observed at 5 cross-shore profiles and accretion (seaward migration of MHW) was observed at 2 profiles.

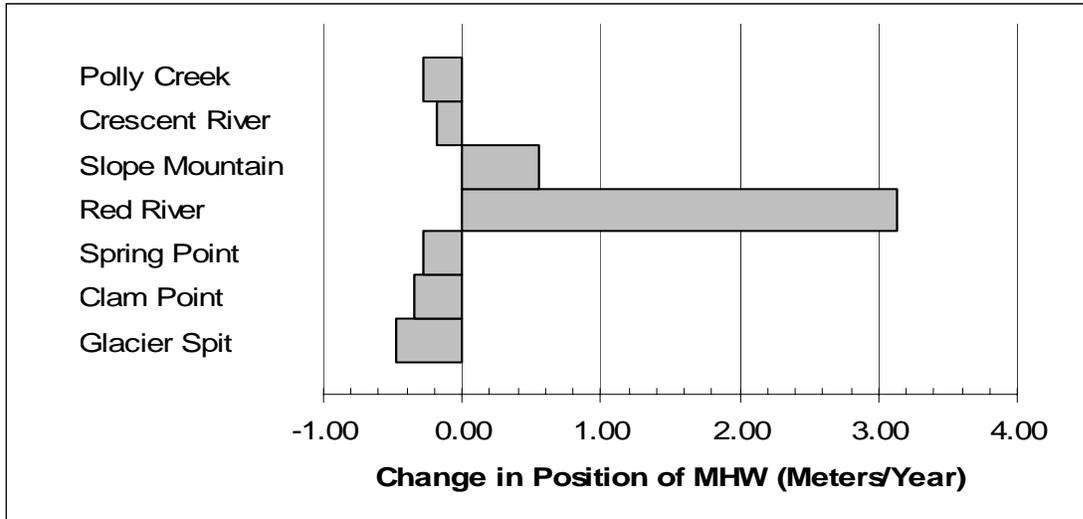


Figure 3. Annual rates of erosion and accretion at cross-shore beach profiles, Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

***Polly Creek and Crescent River-*** The northernmost profiles, Polly Creek and Crescent River, exhibited erosion at MHW of approximately -0.28 and -0.18 m/yr respectively (Figures 4 and 5). Erosion of the bluff edge was even greater, -0.50 and -0.96 m/yr. The Polly Creek and Crescent River sites are backed by bluffs of erodible, unconsolidated glacial sediments. Erosion is primarily occurring by high-energy waves that crash against the base of the bluffs during storm tides. This action, combined with large amounts of groundwater moving through parts of the bluffs, has resulted in large sections of earth falling to the beach (Fig 6). At Crescent River, fallen trees and shrubs associated with bank sloughing restricted mobility of the survey crew and line-of-sight distances needed to accurately complete the survey.

Fallen spruce trees litter the backshore and intertidal flats between the mouth of Crescent River and Polly Creek and suggest a widespread and sustained pattern of bluff erosion along this section of beach. Vertical changes in the cross-shore profiles also reveal erosion (-0.03 m/yr) and suggest that sediment removed from the bluffs is being transported away from the sites by long-shore currents.



Figure 6. Bluff erosion at the Crescent River profile, Lake Clark-Cook Inlet Coastline, 2004.

***Slope Mountain and Red River (Silver Salmon)***- Slope Mountain and Red River cross-shore profiles exhibited accretion at MHW of 0.55 and 3.13 m/yr respectively (Figures 7 and 8). Vertical changes in the cross-shore profiles revealed accretion from the HW storm berm to the beach toe and at MHW averaged 0.10 and 0.06 m/yr respectively. Vertical accretion was most notable at the Slope Mountain profile where the HW storm berm has risen 1.22 meters (1992-2004). A series of HW berms are creating a series of “beach ridges” at this site, characteristic of a shoreline that is building seaward.

At Red River, MHW and the edge of the beach wild rye/beach pea community has migrated approximately 37 meters seaward since the 1994 survey. The backshore landward of the Red River profile and northward to the mouth of the Johnson River supports robust dunes, wide beaches with well-developed berms, and well-developed beach vegetation including large spruce trees extending to the shoreline. All this suggests a long cycle of accretion. Depositional zones are often determined by local hydrodynamics and offshore bathymetry. At the time of this survey, channel migration of Silver Salmon creek (northeast of this profile) was actively eroding a beach that supported buildings and large Sitka spruce trees. Accreting barrier beaches can restrict flow at river mouths and promote alongshore migration of stream channels (Clifton et al 1973).

***Spring Point and Clam Point***- Cross-shore profiles at Spring Point and Clam Point revealed horizontal erosion at MHW of approximately -0.28 and -0.34 m/yr respectively (Figures 9 and 10). Vertical erosion (-0.05 and -0.07 m/yr) is also occurring along the beach profile below MHW. Spring Point is characterized as a high energy cobble beach with a distinctive 'stepped' profile in that it exhibits a number of distinctive steps within the swash zone between MHW and the beach toe (Fig. 11). Step-berm beaches experience waves that break prematurely and re-form as spilling breakers. This also creates distinctive sorting of cobble sizes in the profile due to cobbles being thrown up by waves and tidal action. Although vertical erosion of the summer berm is evident, the position of these steps has changed little during 1992-2004. Cobble beaches, formed by erosion of glacial deposits that were left behind by the retreat of coastal glaciers, extend for 25 km along this region of the LACL coastline.



Figure 11. High energy cobble beach at Spring Point, Lake Clark-Cook Inlet Coastline, 2004.

Clam Point is a sandy pocket beach defined by bedrock outcrops. Boulder and cobble-size clasts are common in the upper profile and beach sediments become finer grained on the seaward end of the profile. Although erosion is occurring at MHW, Clam Point exhibited accretion (0.27 m/yr) in the upper profile extending from the backshore seaward of the HW storm berm. Accretion of the winter berm may be due to more intense storm events or bedrock outcrops which may create localized wave behavior in this pocket beach.

**Glacier Spit-** Glacier Spit exhibited erosion at MHW of approximately -0.48 m/yr (Figure 12). Below MHW and extending to the beach toe, vertical accretion has occurred at a rate of -0.13 m/yr. Glacier spit is a narrow strip of sand that serves as a barrier to wave activity and protects a salt marsh that lies landward. The present configuration of the spit is a product of the topography of glacial till, in-pit of glacial river sediments, uplift associated with the 1964 earthquake, and alongshore sediment transport from waves and currents. Although erosion at MHW is occurring at this profile location (1992-2004), historic aerial photography from the 1950's demonstrates that the spit is growing southwestward. This growth may be coming at the expense of up-current beaches.

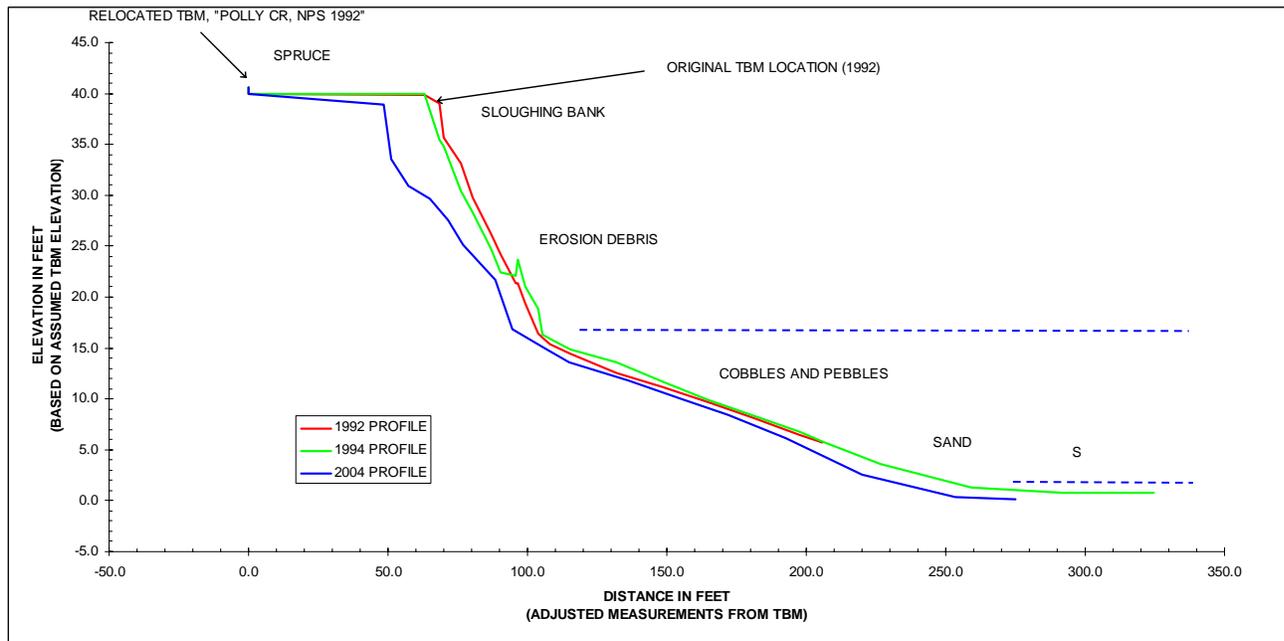


Figure 4. Polly Creek cross-shore beach profile. Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

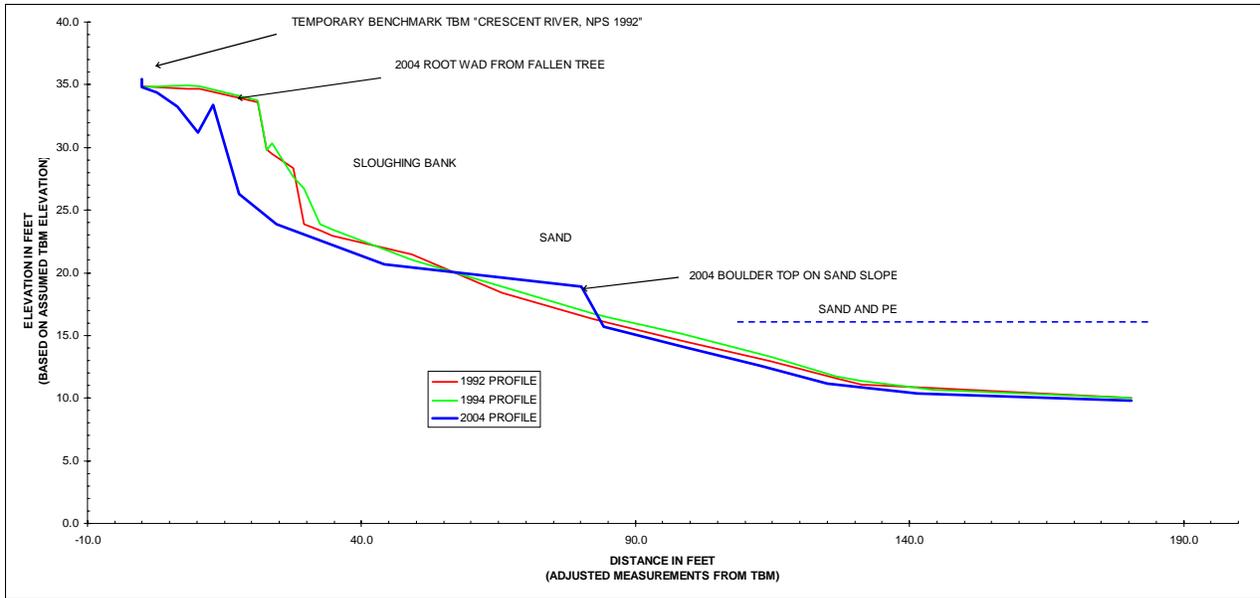


Figure 5. Crescent River cross-shore beach profile. Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

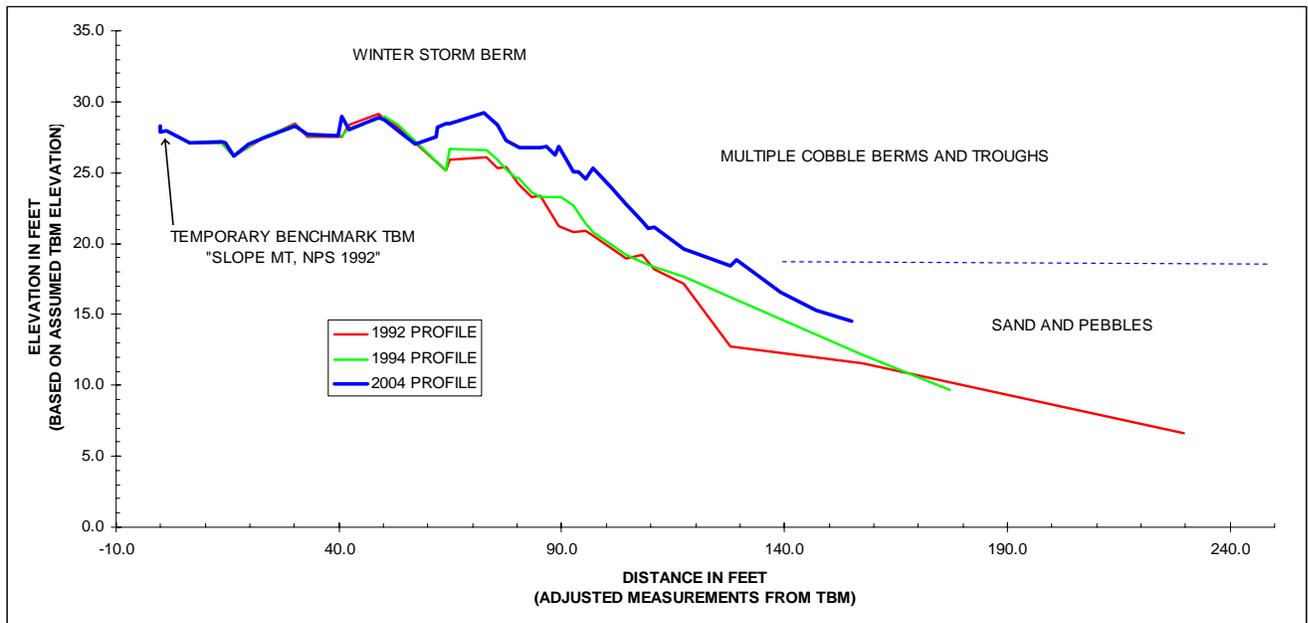


Figure 7. Slope Mountain cross-shore beach profile. Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

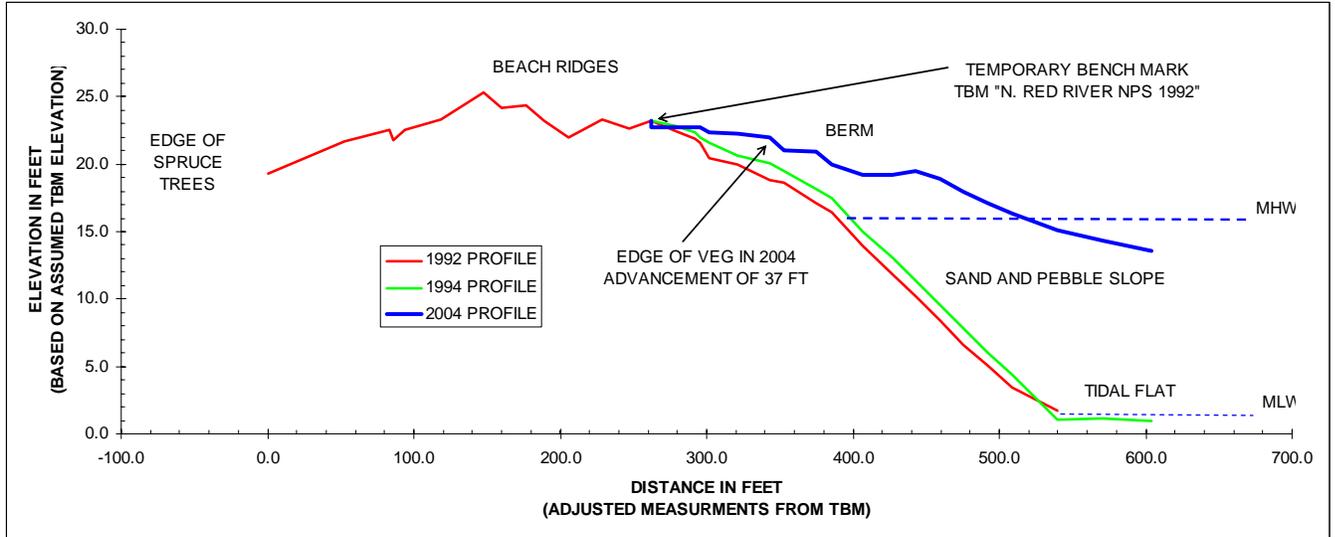


Figure 8. Red River cross-shore beach profile. Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

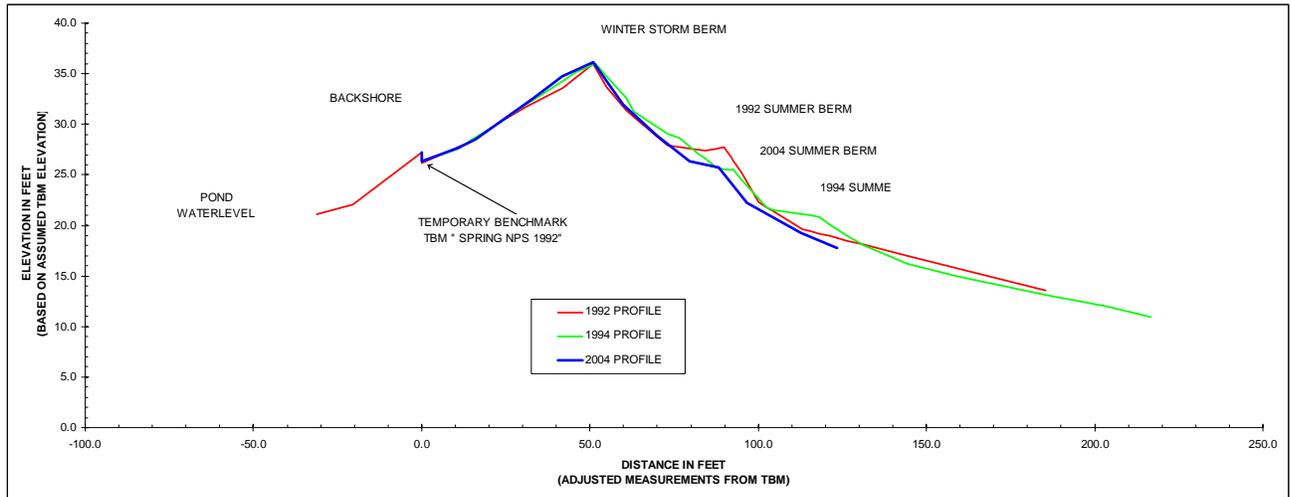


Figure 9. Spring Point cross-shore beach profile. Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

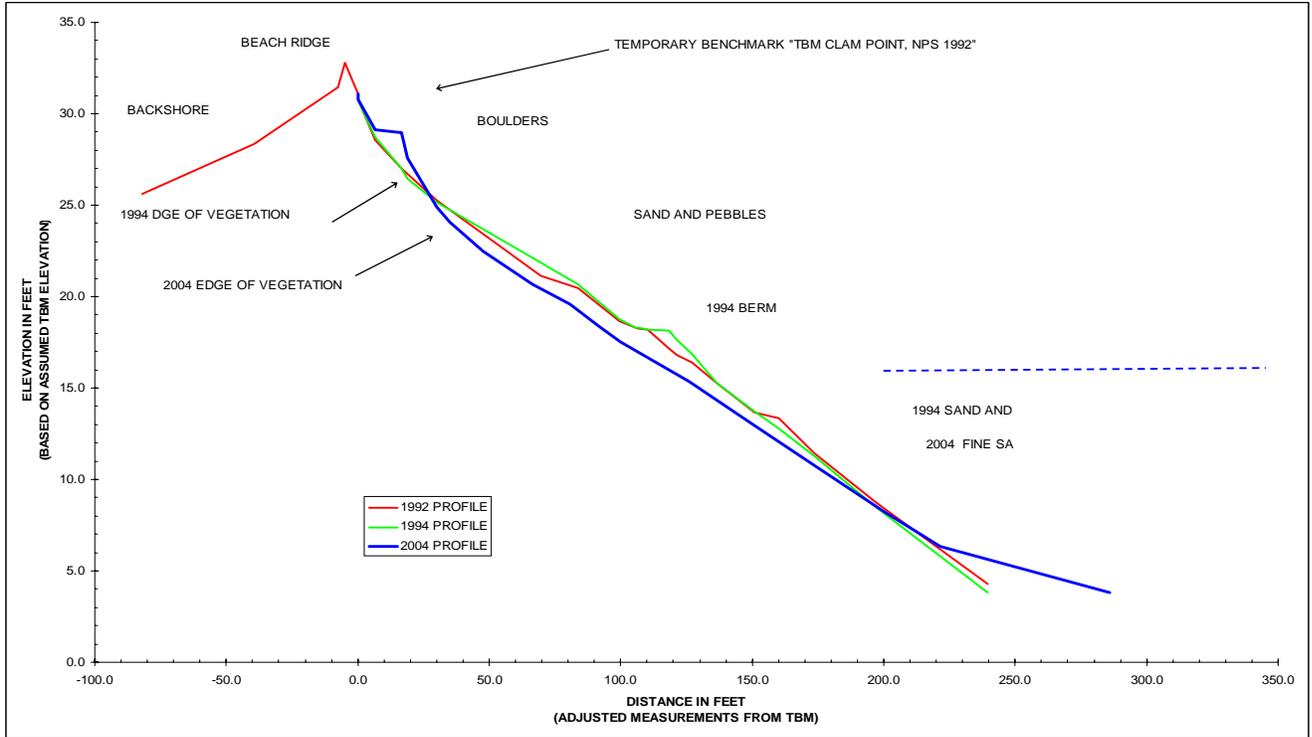


Figure 10. Clam Point cross-shore beach profile. Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

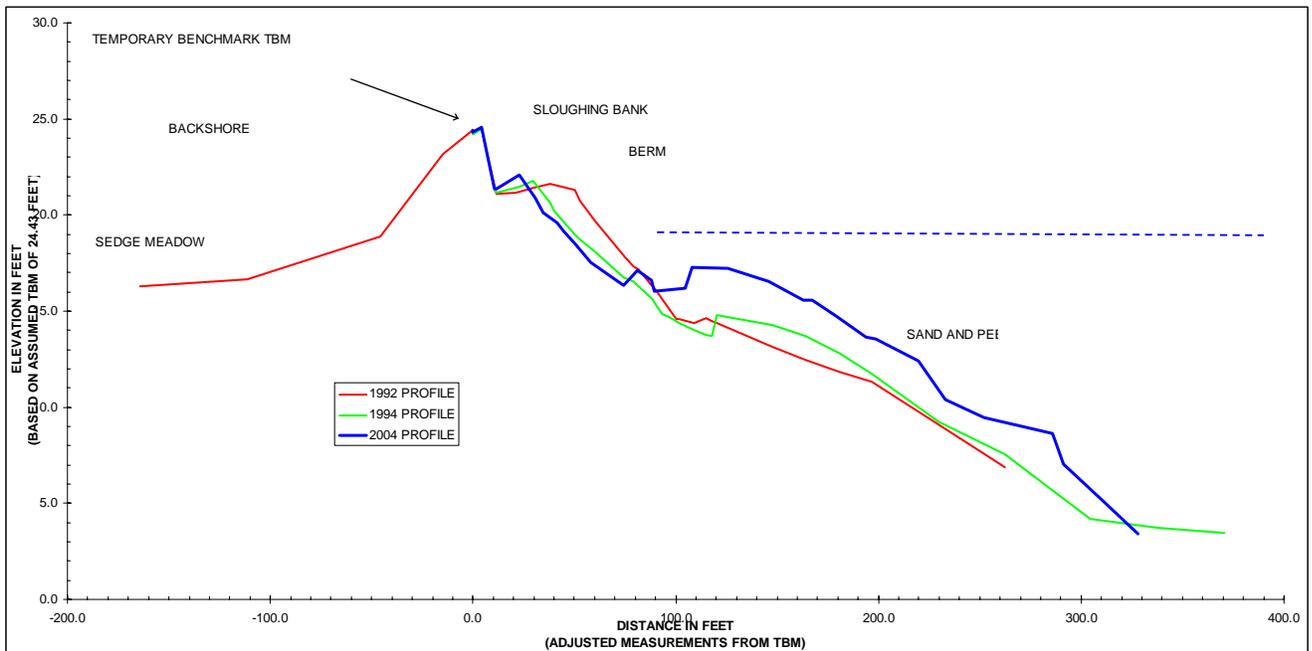


Figure 12. Glacier Spit cross-shore beach profile. Lake Clark National Park-Cook Inlet Coastline, 1992-2004.

## Summary:

The Lake Clark National Park-Cook Inlet Coastline is a morphodynamic system controlled by variables such as sediment supply, regional tectonics, climatic forcing, and to a growing extent, human intervention. There are a number of significant results and observations that emerge from the series of cross-shore beach profiles established in 1992 and resurveyed in 1994 and 2004. These results, although site specific, and temporally and spatially discontinuous, provide a growing understanding of the behavior of the park's marine shoreline to environmental changes.

Comparisons between 1992 and 2004 revealed variation in rates of erosion and accretion across the Lake Clark National Park coastline. Erosion (landward migration of MHW) was observed at 5 cross-shore profiles and accretion (seaward migration of MHW) was observed at 2 profiles. Annual average rates of erosion and accretion ranged from -0.18 to -0.50, and 0.55 to 3.13 m/yr respectively. Similar patterns of erosion and accretion were observed between 1992 and 1994 by Schoch (1996).

Cross-shore profile surveys of the Lake Clark Coastline reveal that large scale patterns of shoreline change involving the loss or gain of sediment are more complex than alongshore sediment transport accumulating against a linear boundary. While alongshore sediment transport along Western Lower Cook Inlet is generally southwestward (Mundy 2005), local onshore and offshore features such as shoreline orientation, bathymetry, tides, sediment supply, and circulation patterns create localized zones of stability, erosion, and accretion. Hence, a simple extrapolation of shoreline trends observed at one location could potentially be wrong in both magnitude and direction if applied to a greater region.

Although cross-shore beach profiles are two-dimensional representations that provide an assessment of the current shoreline position at one alongshore location, combining cross-shore profile measurements with observations of patterns of vegetation succession, historic photographs, ShoreZone videography (Harper and Morris 2003), and erosive features such as landslides, spatially extends the interpretation of changes documented at profile sites. Robust backshore dunes, wide upper intertidal beaches with well-developed berms, early successional stages of beach wild rye/beach vegetation, all suggest that beaches are accreting and growing seaward between the Red River and the west entrance to Tuxedni Channel. In contrast, sloughing bluffs, uprooted mature spruce trees littering the backshore and at MHHW, and an abrupt edge along the beach wild rye/beach vegetation community, suggest that erosion and landward migration of the shoreline is occurring between Chisik Island and Polly Creek, and between West Glacier Creek and Spring Point.

A major question to evaluate as the SWAN initiates long-term monitoring is whether recent (1992-2004) park-scale shoreline change rates indicate a long-term trend of shoreline progradation, an increasing trend of erosion, or if the shoreline is adjusting to

a dynamically new position, such as uplift from the 1964 earthquake. A growing body of evidence suggests that the winter storms in the Gulf of Alaska are growing in intensity and frequency, and that this trend may be linked to climatic warming. Surface air temperature projections, derived from several climate models of the Gulf of Alaska, predict that the warming trend will continue. Storm-generated beach erosion combined with sea level rise, also linked to climate change, could effect future rates of shoreline change.

Cross-shore beach profiles are the primary methodology used to understand historical coastal evolution and often to predict future coastal change. Other techniques, such as using differential GPS (DGPS), is not as accurate as standard surveying using a rod and level, but its use may be justified by both the reduction in survey time and the magnitude of change observed on the high-energy beaches of the SWAN. DGPS surveys of the position of MHW are often done using all terrain vehicles or on foot and can cover large sections of coast within a single low tide period. Light Detection and Ranging (LIDAR) data is presently the state of the art in three-dimensional coastal shoreline data collection. Protocols for the use of LIDAR are under development and testing in the Northeast Coastal and Barrier Island Network and may be applied to SWAN if partnerships materialize that make this technique affordable. In lieu of this, SWAN may use ground-based approaches, such as cross-shore profiles, that can be integrated with other marine nearshore monitoring tasks. In the near future high-resolution satellite imagery such as IKONO's may also be employed for shoreline change analysis in the SWAN.

### ***Management Implications, and Recommendations for Future Monitoring--***

- Erosion of bluffs and shorelines has implications for protection and management of park structures, natural and cultural resources, private inholdings, and the need for future monitoring. If it continues at the current rate, bluff erosion between the Crescent River and Polly Creek will contribute large volumes of sediment and woody debris into Tuxedni Bay/Channel. Woody debris that accumulates on tidal flats and salt marshes acts as a sediment trap and can influence salt marsh plant communities and their use by wildlife.
- Shoreline erosion in Chinitna Bay between Glacier Spit and Clam Point may directly threaten archeological sites near Clam Cove, the Chinitna Bay Ranger Cabin, and the former Haeg property at Horn Creek acquired by the park in 2005. In 2001, beach erosion 250 meters east of Clam Point undercut, toppled, and buried the last standing remnant of a Tertiary fossil forest.
- Changes in the position of MHW has jurisdictional implications for park management. At the Red River Profile, the 2004 'park boundary' was 37 meters seaward from where it was in 1992. This could become an issue both

in zones of sediment erosion and accretion, especially in the Silver Salmon Creek/Johnson River area where private land inholdings, state jurisdiction, and federal jurisdiction is already clouded.

- Coastal rivers within zones of beach accretion may exhibit more dynamic patterns of river channel migration were they enter the sea. Since 2003, the Red River, Silver Salmon Creek and the Johnson River have all cut new channels within their coastal floodplain. At Silver Salmon Creek, beach erosion associated with channel migration forced a private inholder to relocate buildings that were on a barrier beach.
- Future monitoring efforts should include the relocation and survey of the three beach profile transects (Bear Creek, South Shore Tuxedni and Rusty Mountain) not visited during 2004. Although the changes at these sheltered beach sites may not be as flashy as those along the outer coast, they will provide important data on trends in erosion/accretion adjacent to salt marshes that are targeted for long-term monitoring of vegetation and intertidal invertebrates.
- TMB's at Polly Creek and Crescent River sites need to be relocated landward because they are at risk from bluff erosion. The Crescent River TMB was < 5 meters from the edge of the bluff in 2004.

### Literature Cited

- Bennett, A.J. 1996. Physical & Biological Resource Inventory of the Lake Clark National Park-Cook Inlet Coastline, 1994-96. Lake Clark National Park and Preserve Kenai Coastal Office. Kenai, AK. 137 pp.
- Boak, E.H. and L.L. Turner. 2005. Shoreline Definition and Detection: A Review. *Journal of Coastal Research* **21**:618-701
- Clifton, H.E., Phillips, R.L., and Hunter, R.E. 1973. Depositional structures and processes in the mouths of small coastal streams, southwestern Oregon, *in* Coates, D.R., ed., *Coastal geomorphology*: Binghamton, State University of New York, Publications in Geomorphology, p. 115-140
- Dames and Moore. 1978. Drilling fluid dispersion and biological effects study for the Lower Cook Inlet C.O.S.T. well. Report to Atlantic Richfield Co., Anchorage, AK 309 pgs.

- Freethy, G., and Scully, D. 1980. Water Resources of the Cook Inlet Basin, Alaska. USGS, Hydrologic Investigations Atlas, HA-620, 1980
- Harper, J.R. and M.C. Morris 2003. ShoreZone mapping protocol for the Gulf of Alaska. Contract Report by Coastal and Ocean Resources Inc., Sidney, BC for the Exxon Valdez Oil Spill Trustee Council, Anchorage, AK, 61pp. ([www.CoastAlaska.net](http://www.CoastAlaska.net))
- Morton, R.A., Leach, M.P., Paine, J.G., and Cardoza, M.A. 1993. Monitoring beach changes using GPS surveying techniques, *Journal of Coastal Research* **9**:702 - 720
- Mundy, P.R. ed. 2005. *The Gulf of Alaska: biology and oceanography*. Alaska Sea Grant Program, Fairbanks, AK
- Ruggiero, P., B. Voigt and G. Kaminsky. 2000. Beach Monitoring for Enhanced Decision-making. Coastal Society 17th Conference Coasts at the Millennium, July 2000, Portland, Oregon.
- Schoch, G.C. 1996. The classification of nearshore habitats: a spatial distribution model. M.S. Thesis. Coll. Oceanic and Atmospheric Sci., Oregon State Univ., Corvallis 146 pgs.

**Appendix A. Coastal Lake Clark National Park and Preserve Beach Profiles-  
Example photo dataset for Polly Creek.**

J:\SWAN\Monitor\_Development\Pilot\_Projects\Habitat\_Mapping\CusickJ\_L  
ACL\_Beach\_Profiles\2004\_ReSurvey\Data\Site\_Photos\SiteWebPages

**Polly Creek Beach Profile**  
2004 Survey

---

 <p><a href="#">PollyCreekProfile.bmp</a> Joel Cusick Misc LACL</p>	 <p><a href="#">Polly_Ck_Overview.JPG</a> Joel Cusick Site Overviews LACL</p>	 <p><a href="#">Polly_Ck_IMG_2255_tag.jpg</a> Joel Cusick Site Overviews LACL</p>	 <p><a href="#">Polly_Ck_IMG_2256_tag.jpg</a> Joel Cusick Site Overviews LACL</p>	 <p><a href="#">Polly_Ck_IMG_2258_tag.jpg</a> Joel Cusick TBM Photos LACL</p>
 <p><a href="#">Polly_Ck_IMG_2260_tag.jpg</a> Joel Cusick TBM Photos LACL</p>	 <p><a href="#">Polly_Ck_IMG_2261_tag.jpg</a> Joel Cusick Profile Views LACL</p>	 <p><a href="#">Polly_Ck_IMG_2263_tag.jpg</a> Joel Cusick Profile Views LACL</p>	 <p><a href="#">Polly_Ck_IMG_2264_tag.jpg</a> Joel Cusick Site Overviews LACL</p>	 <p><a href="#">Polly_Ck_IMG_2266_tag.jpg</a> Joel Cusick Profile Views LACL</p>

Polly Creek - TBM Location from perspective of Level 2004 Beach Profiles - Coastal LACL



Polly Creek - Alon on eroded bluff. 2004 Beach Profiles - Coastal LACL

