

TECHNICAL SUMMARY

STUDY TITLE: Assessment of the Direction and Rate of Alongshore Transport of Sand and Gravel in the Prudhoe Bay Region, North Arctic Alaska

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CONTRACT NUMBER: 1435-01-02-CA-85294; TASK ORDER (TO):39380 or M05AC12292

SPONSORING OCS REGION: Alaska

APPLICABLE PLANNING AREA: Beaufort Sea

FISCAL YEARS OF PROJECT FUNDING: FY 2005-2009

COMPLETION DATE OF REPORT: August 2010

COSTS BY FY: FY 2006: \$84,048

FY 2007: \$116,352

FY 2008: \$68,079

CUMULATIVE PROJECT COST: \$268,479

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KEY WORDS: Alongshore sand and gravel transport in the Alaskan Arctic, storm-surge model, time-series wave climate.

BACKGROUND:

Understanding the principles that govern coastal sediment dynamics has numerous practical applications, for example, in designing and maintaining coastal engineering structures, predicting the fate of pollutants discharged into the nearshore, identifying alteration in the natural mass balance of coastal sediments, and environmental problems relating to coastal erosion, beach nourishment, and mining of placer minerals.

In North Arctic Alaska, estimates to-date on alongshore sediment drift in the North Slope are based on limited theoretical deductions from wind-wave-current statistics, study of historical charts and aerial photos or data from too-distant study areas. Rescaling and calibration of numerical sediment transport models for the arctic shoreline will be invaluable to industry in planning coastal and offshore infrastructure and will support effective management of the coastal region by the regulating governing agencies.

OBJECTIVES:

Study objectives included:

- 1) To conduct a comprehensive survey of the literature and develop an annotated bibliography with special reference to the north Alaskan Arctic coast,
- 2) To record the beach relief during two summer time-intervals,
- 3) To record real time wind velocity and direction, and wave height and direction in open water conditions for the Narwhal Island region;
- 4) To use dyed sand and pilot use of Passive Integrated Transponders determine the seasonal direction and volume of the transport of sand and gravel for a barrier island beach, and
- 5) To reconfigure and downscale an existing wide-scale Beaufort Sea storm surge model.

DESCRIPTION:

The study area consists of Narwhal Island, a micro-tidal, mixed sand-gravel barrier island and the contiguous near shore north of the island. The study area is exposed to severe ice conditions for eight to nine months yearly when pervasive ice push action by shore-fast ice is a major factor for mass sediment transport on the beaches. During the short summer sediment drift is caused by alongshore currents and storm driven wave action.

*P.I.'s affiliation may be different than that listed for Project Manager(s).

Sediment tracer experiments were conducted on Narwhal Island using gravel tagged with 12 mm long Passive Integrated Transponders (PIT). Four replicate suites of tagged sediments were injected at the mid-tide waterline at four sites. The sand transport assessment included discharge of 13Kg of fluorescent-dyed sand at each of the sites. Tagged-gravel and sand samples were systematically collected during spring and summer.

Theoretical computation of the direction and rate of volume transport of sand during open water season was completed based on the time-series of wave and wind climates. The wave climate time-series was recorded in summer 2007 by a SonTek 1.5 MHz Acoustic Doppler Current Profiler (ADCP) deployed for a month on the sea floor at 10m water depth. The roles of the permanent barotropic currents and wind-driven circulations were investigated in detail. A simple sediment transport semi-empirical model was applied as the first order approach to study the peculiarities of sediment motion around McClure Islands. In an effort toward understanding the potential impact of episodic storm events on hydrodynamics and alongshore sediment transport in the study area, a set of 2-D coupled ice-ocean models were reconfigured based on the data from this study.

SIGNIFICANT CONCLUSIONS

A survey on the 26 July, 2006 indicated that 42% and 22% of the PIT tagged gravel injected in June 2006 at beach sites 1 and 2, respectively, were intercepted. These gravel particles had drifted east and west within 1m of the marker stakes. Of the 21 tagged gravels from site 1 three were intercepted at ~1 m subtidal zone. None of the tagged gravel particles were identified on the beach in late August 2006. A survey on 25 July, 2007 of the beach located only one of the 200 tagged gravel particles originally injected. This gravel had drifted 29 m westward from the June 2006 point of injection. The fate of the rest of the tagged gravel particles is unknown. It is likely that during winter of 2006-2007, the tagged gravels were reworked by beach ice and emplaced either under sand-gravel mounds at depths beyond the PIT reader's detection limit (~0.3m) or dragged to the subtidal zone. Empirical studies in the Alaskan arctic beach indicate that use of PIT tags has a potential in assessing the short-term direction and rate of alongshore transport of gravel only in summer. Application of the marker for the rest of the year was frustrated by the inability to detect the tagged gravel particles that were buried under ice-pushed sand-gravel piles. It would seem gravel transport in the Alaskan arctic beach can be three times greater during ice-stressed months than during summer.

The 2006 and 2007 surveys showed that the maximum displacements seaward on the beach of the tagged gravels from berm sites 1, 2, 3, and 4 were 6.6m, 2.46m, 2.15m and 1.85m respectively. These relatively short displacements of the gravels were surprising considering that there were summer storm surges that extended up to the berm followed by backwash of the storm-surge along the beach slope.

The use of dyed sand was unsuccessful for estimating alongshore sand transport as no dyed sand particles from the beach samples were detected under the microscope. Presumably, the dyed sands were rapidly lost (within a month) to the subtidal zone after their injection on the beach sites. However, the volume rates (m^3 per two-hour measurement interval) of potential alongshore sand transport were computed based on the ADCP record, using the SWAN wave propagation model, the CERC sand transport equations and wind data coinciding with the wave climate time-series. The total amount of material (m^3) transported during the storms was 55.4, 81.2, 121.6 and 1191.6, all of which were from east to west. The average transport rates for each storm (m^3/hr) were 0.52, 0.99, 1.24 and 33.1, respectively.

STUDY RESULTS:

The use of dyed sand as a marker was unsuccessful for estimating alongshore sand transport as there was no recovery of marked samples. The attempt to use PIT tags was somewhat successful and a useful pilot study for trying this new technology to trace gravel transport on ocean beaches, especially those that are ice impacted. Movement of PIT tagged gravel was detected on the beach at Narwhal Island by late July 2006 and had moved 1 meter east and west from the marker stakes. A survey in 2007 located only one tagged gravel which had moved 29 m west of the injection point. Gravel transport appears to be greater during ice-stressed months than during the summer. Further research should be conducted

involving different sizes and shapes of gravel and addressing gravel transport capacity in terms of annual volume and tonnage.

STUDY PRODUCTS

During the project period five quarterly reports and a final report were submitted to the CMI, and research progress was presented at the 2007 and 2008 CMI/MMS Annual Research Reviews. Additional presentations included:

Naidu, A. S., Kelley, J. J., Kowalik, Z., Lee W., Miller, M. C., Ravens, T. M., Smith, O. P. And Streever, W. 2007. Assessment of longshore transport rates of gravel and sand on Narwhal Island, north Arctic Alaska: approaches, challenges and progress. Oral presentation at the 58th Annual AAAS meeting, September, 2007, Anchorage, AK.

Ravens, T. M., Naidu, A. S. and Lee W. 2007. Morphodynamics of a North Slope barrier island (Narwhal Island, North Arctic Alaska) 1955-2007. Oral presentation at the 58th Annual AAAS meeting, September, 2007, Anchorage, AK.

Naidu, A. S., J. J. Kelley, Z. Kowalik, W. Lee, M. C. Miller, T. M. Ravens, O. P. Smith and R. Gens. 2008. Use of Passive Integrated Transponder tag for assessing transport rate of gravel, north Arctic Alaska. Proc. (Poster) Ocean Sciences Annual Mtg., March 2008, Orlando, FL.

A text enumerating details on the development of the storm-surge model was submitted on a CD to the CMI. In addition, result of the search on the major literature on alongshore sediment transport with special reference to related sediment- and hydro-dynamics of Alaskan Arctic was submitted on a CD to the CMI.

This project provided an opportunity for the training of three undergraduate Alaska Native students and one graduate student in the field and laboratory.

This project was conducted by a partnership of a multidisciplinary group. Investigators from the University of Alaska Fairbanks (S. Naidu, J. Kelley and Z. Kowalik) and Anchorage (O. Smith, T. Ravens, W. Lee), the Pacific Northwest National (PNNL), Marine Sciences Laboratory (MSL) – Sequim, WA), and Coastal and Ocean Concept, LLC, Sequim, WA (M. Miller), with field logistics support provided by the British Petroleum Exploration, Alaska (W. Streever).

