4.2 AN INTEGRATED ASSESSMENT OF THE IMPACTS OF EXTREME EVENTS ON THE COASTAL ZONE IN A SMALL ALASKAN COMMUNITY

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PROLOGUE

On Thursday, 3 Oct 1963, an intense storm struck Barrow, Alaska with little warning. The storm was “unique in its violence and consequences” (Schafer 1966). The cyclone that produced the strong winds, erosion, and flooding in Barrow originated along the Arctic front over Siberia around 145.6^{o}E late on 1 Oct 1963. Over the next 24 hours it traversed to the coast and continued northward on a track typical for such systems. However, shortly after 9 pm (all times Alaska Standard Time) on 2 Oct, the storm turned eastward and commenced a rapid deepening, reaching an estimated minimum central pressure of 976 hPa at 11 am on 3 Oct, while located in the Beaufort Sea north of Barrow (Lynch et al. 2003). The strongest winds at Barrow were reported between 1 and 3 pm with gusts possibly as high as 70 kts (36 ms^{-1}, Hume and Schalk 1967). Guy Okakok (1963), then the Tundra Times correspondent in Barrow, wrote “I am 60 years old now … and I have never seen the winds as strong as we had that day on October 3. High winds and high water everywhere.”

The sea level started to rise at around 5 am on 3 Oct, with the surge between 3 and 3.5 m sometime between 3 and 4 pm that afternoon (Hume and Schalk, 1967). The storm “moved over 200,000 cubic yards of sediments, which is equivalent to 20 years’ normal transport” (Hume and Schalk 1967). The bluffs on the southern edge of Barrow retreated as much as 10 m during this storm, exposing large ice masses that subsequently melted, causing some further shoreline collapse. A temporary lake was created north of town which had an elevation of almost 3 m above sea level.

There was little warning to help the community respond. Poor radio propagation had prevented the Weather Bureau from receiving the normal weather reports from Soviet Siberia for several days (Anon., 1963). “There was no warning, which meant, the people of Barrow had to do some quick thinking to save themselves during the onslaught” (Rock, 1963).

Figure 1. A house (owner unidentified) is swept away during the 1963 flood. (Photo by Grace Redding).

1. INTRODUCTION

The city of Barrow, Alaska, the northernmost city in the United States, is situated on the shores of the Arctic Ocean (Figure 2). The Oct 63 storm caused more damage than any other storm in historical records or living memory, but there have been many other damaging storms. The storms of Sept 12 and 20 1986 first exposed artifacts, including the remains of ancestors, and then washed them out to sea. Since then, the people of Barrow have been striving to reduce their vulnerability to coastal erosion and flooding arising from extreme cyclones. Their longer-term concern is that global warming may increase Barrow's vulnerabilities in the future.

Our work has focused on an effort expand the range of informed options open to the people of Barrow to address this problem. To this end, we have compiled what is known by residents and scientists about trends and processes in atmospheric circulation, sea ice, erosion and other factors affecting Barrow over the past half century. We have worked to understand how these trends and processes interact in the series of extreme events to date. While much uncertainty remains, it is nevertheless reasonable in our view for Barrow to act on a variety of policy alternatives to reduce its vulnerabili-

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ties, provided arrangements are made to learn from each extreme event and adjust future policies accordingly. The policy decisions will, of course, be made by the Barrow community on the basis their values and knowledge, taking into account whatever outside advice they deem appropriate.

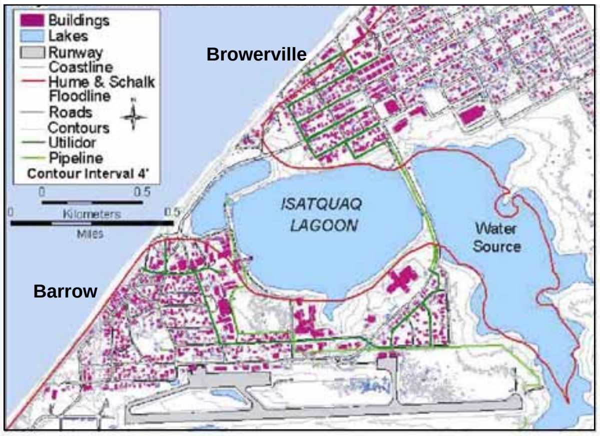

Figure 2: The city of Barrow in 1997, showing the suburb of Browerville and the airport to the south.

2. CLIMATOLOGY MADE LOCAL

Findings regarding the trends and variations in Barrow area climate do not uniformly match Arctic-wide or even sectorial trends documented in the literature. Briefly, the observed changes in the last 50 to 80 years (depending on available records) are as follows:

- **Wind Speed:**Average wind speed decreased from around 1970 through to 1985, followed by an increase since then. Wind speed variability has also increased markedly since 1985. Return periods for extreme high wind events are changing non-linearly with time, leading to high uncertainty for the future.
- **Wind direction:**There has been a small shift in the last decade to more easterly winds, but there are no trends evident in the directions of extreme wind.
- **Air temperature:**The trend of increasing minimum, maximum and average daily temperature in the years before 1990 has reversed in the last decade, but the frequency of extremely cold days and the persistence of cold snaps are both still decreasing.
- **Snow:**Snow cover onset has changed little. Snow melt onset is almost one month earlier in the last 50 years, and shows a rapidly increasing variability and hence decreasing predictability.
- **Sea ice:**Annual ice concentrations have decreased by 3% to 9% for the Beaufort and Chukchi seas, the trend increasing towards the west. The total area of multiyear ice is decreasing. Melt distribution is experiencing increasing variability.
- **Ocean temperature:**Ocean surface temperatures along the Chukchi Sea coast near Barrow have increased by about 2^{o}C over the period from 1982-2002, with a slight cooling nearshore in winter.
- **Permafrost:**The active layer depth has increased until recent years when it has decreased in line with average temperatures. However, the relationship between thawing degree days and average thaw depth has changed. The same surface energy input in the 1990s produced around 70% of the thaw depth achieved in the 1960s.
- **Erosion:**Nearly all of the mainland coast has experienced erosion. Accretion has been limited to short stretches of widening beach along the Chukchi coast and shifting of nearshore spits and bars. Since 1948, the bluffs south of Barrow have retreated only 0.2 m (not shown), compared to an average of 17.6 m and a maximum of 35 m near Barrow (Figure 3).

3. CONSEQUENCES FOR THE COAST

These changes interact with each other to contribute to the vulnerability of the community. Certainly the temperature increases noted throughout much of the record, particularly in the Spring, are a chief cause behind the changes seen in snow melt, sea ice retreat, permafrost thaw and ocean temperatures. The increase in temperature variability is also reflected in the increase in variability of snow melt date and ice retreat date. This increasing variability implies decreasing predictability by statistical, physical modeling and traditional knowledge means, and strongly impacts planning at a community and an individual level.

Many of these records contribute to the occurrence of flooding events and large erosion events. Flooding and erosion are both linked to the confluence of open water (allowing build up of waves), high *westerly* winds (allowing wave setup and Ekman transport) and low surface pressure (allowing the inverse barometer effect). Possible rising sea level in this region, not well characterized at present, will also play a part. Permafrost thaw destabilizes coastal sediments and renders them more vulnerable to erosion. Conversely, permafrost thaw is accelerated locally through exposure by erosion.

In order to estimate the impact of the October 1963 storm, we obtained aerial photographs bracketing the storm, from August 1962 and July 1964 (Figure 4). Erosion was found to have occurred along the bluffs, ranging from low values in the southwest up to 10 m toward the northeast. The highest levels of erosion occurred near runoff outlets and the “old Barrow” town site. There was a high variability of erosion along this short coastline segment. A mixture of erosion and accretion

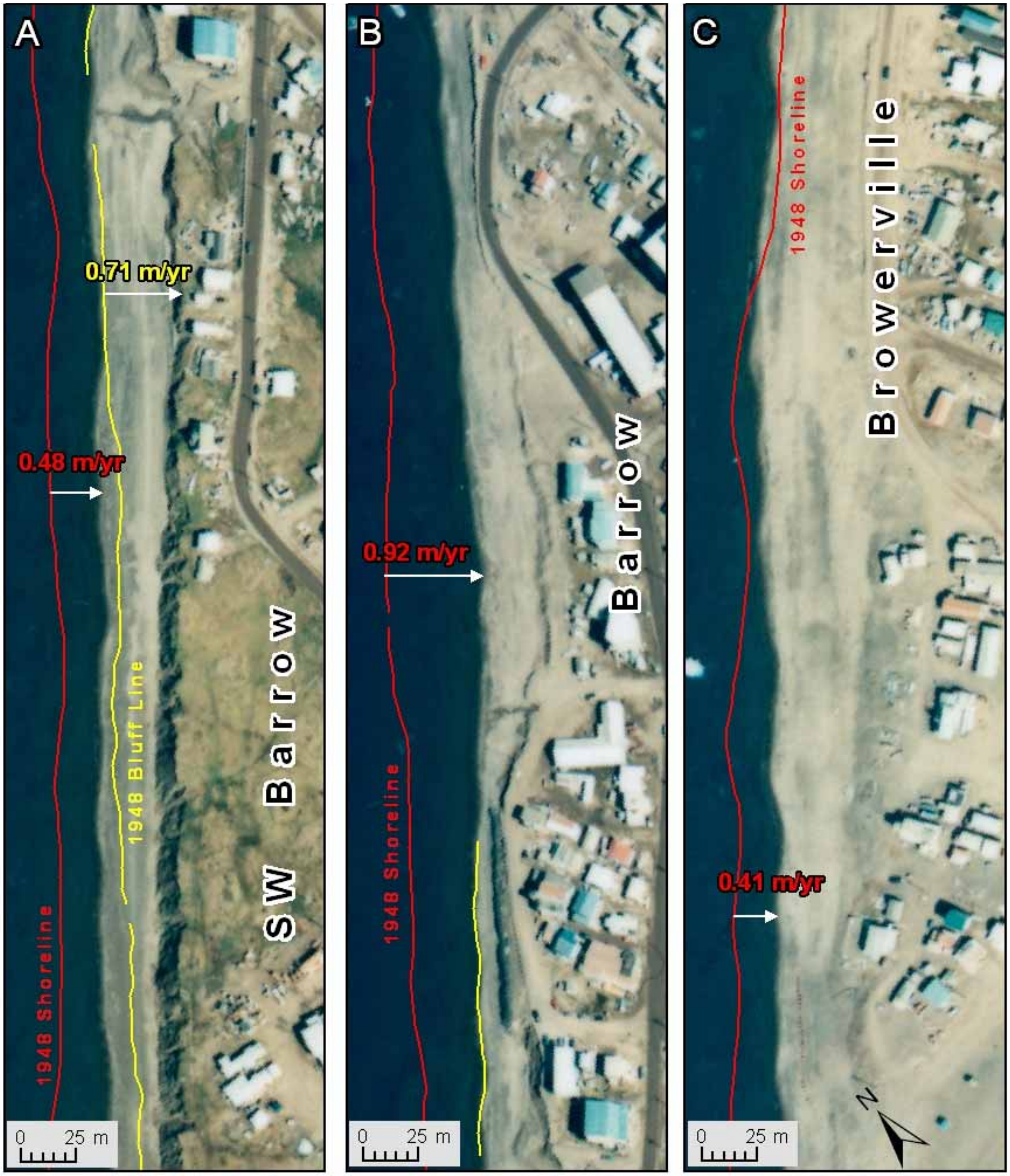

Figure 3. Orthorectified 1997 aerial photography of Barrow and Browerville with overlaid 1948 shoreline and bluff data. Both shoreline and bluff erosion rates are spatially variable, averaging 21 m and 26 m respectively in 50 years, with some accretion in Browerville. The erosion rates are 50% smaller than erosion rates for the ice-rich, peaty shorelines east of Barrow but significant for policy purposes. Location accuracy is 3.2 m for shorelines and 3.8 m for bluff lines (errors due to orthorectification, digitizing, and transient waterline shifts from tides and wave setup). (Credit: L. Lestak).

over the two-year period was found to have occurred at the water line along the northeast segment, again highly spatially variable with an average of 3.2 m. Erosion is also associated with human activities; sometimes, paradoxically, those very activities intended to protect the shoreline. Many of the buildings that were lost in the great storm of October 1963 were in areas where the beach had been mined for gravel for construction and fill.

4. IS RISK FROM EXTREME STORMS INCREASING?

Over the past 60 years, the characteristics of extreme wind occurences in Barrow have changed, and these changes differ by season. Although there is little apparent linear trend in the average or highest winds in any season, extreme winds in the fall, when ice is far from the coast and hence the community is most vulnerable to flooding and erosion, appear to have decreased slightly in recent years. A documented increase in summer cyclone intensity (Lynch et al. 2004) is reflected in a small, but probably not significant, increase in strong winds during the summer months. Overall, there are no significant long-term linear trends in wind speed extremes in Barrow.

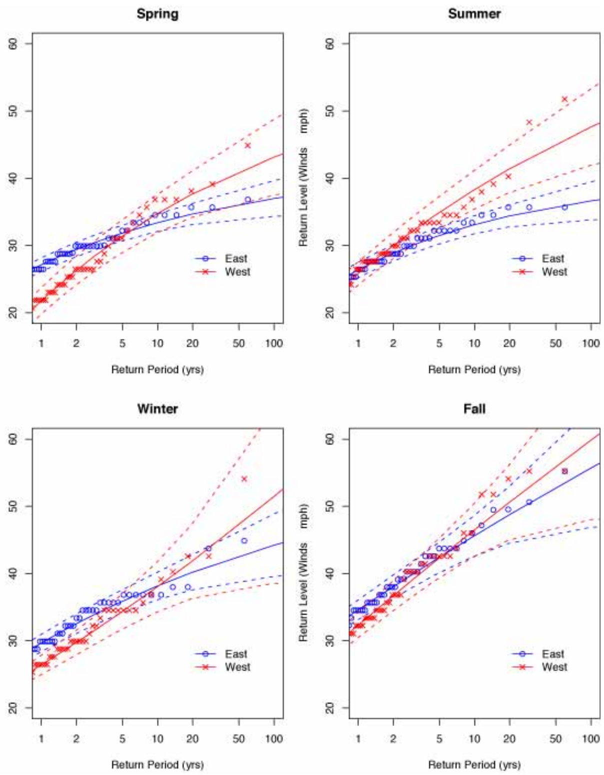

Figure 5. Return wind speeds, by season and by direction, using Barrow data from 1945 through 2003. (Figures 5 and 6 courtesy M. Pocernich, NCAR).

In extreme value statistics, the concepts of return levels and return periods are often used. Here, the return level refers to a high wind speed and the return period is an expression of the probability of the return level being reached in a single year. Figure 5 shows the relationship between return level for maximum wind values and return period for Barrow, for easterly and the more damaging westerly winds.

Figure 5 is based on the assumption that the parameters are stationary. This is an assumption that is difficult in practice to verify. To explore the possibility that the population is changing with time, a non-parametric trend was estimated (Figure 6). The analysis suggests that the return levels may indeed be changing with time. Since these values are calculated with a moving window of data, the values at the beginning and end of the series contain the most uncertainty. The shapes of the trends may suggest that the trends might not be best fitted by a simple linear change. In fact, a quadratic fit produces a statistically significant model, which corresponds to our intuition from observing that winds were lower in the 1970's than before or since (Lynch etal. 2004).

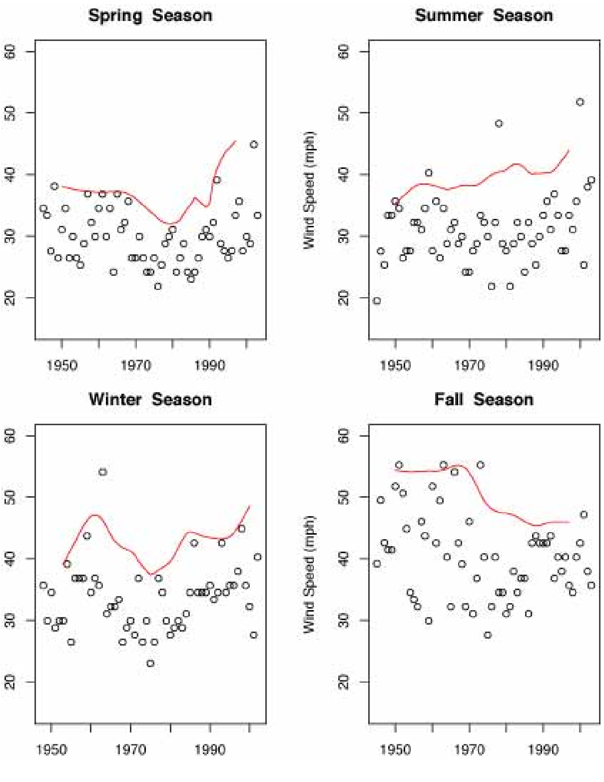

Figure 6. Twenty year return levels and bootstrapped confidence intervals based on 100 resamples conducted for each year. The red line indicates the results from the original data.

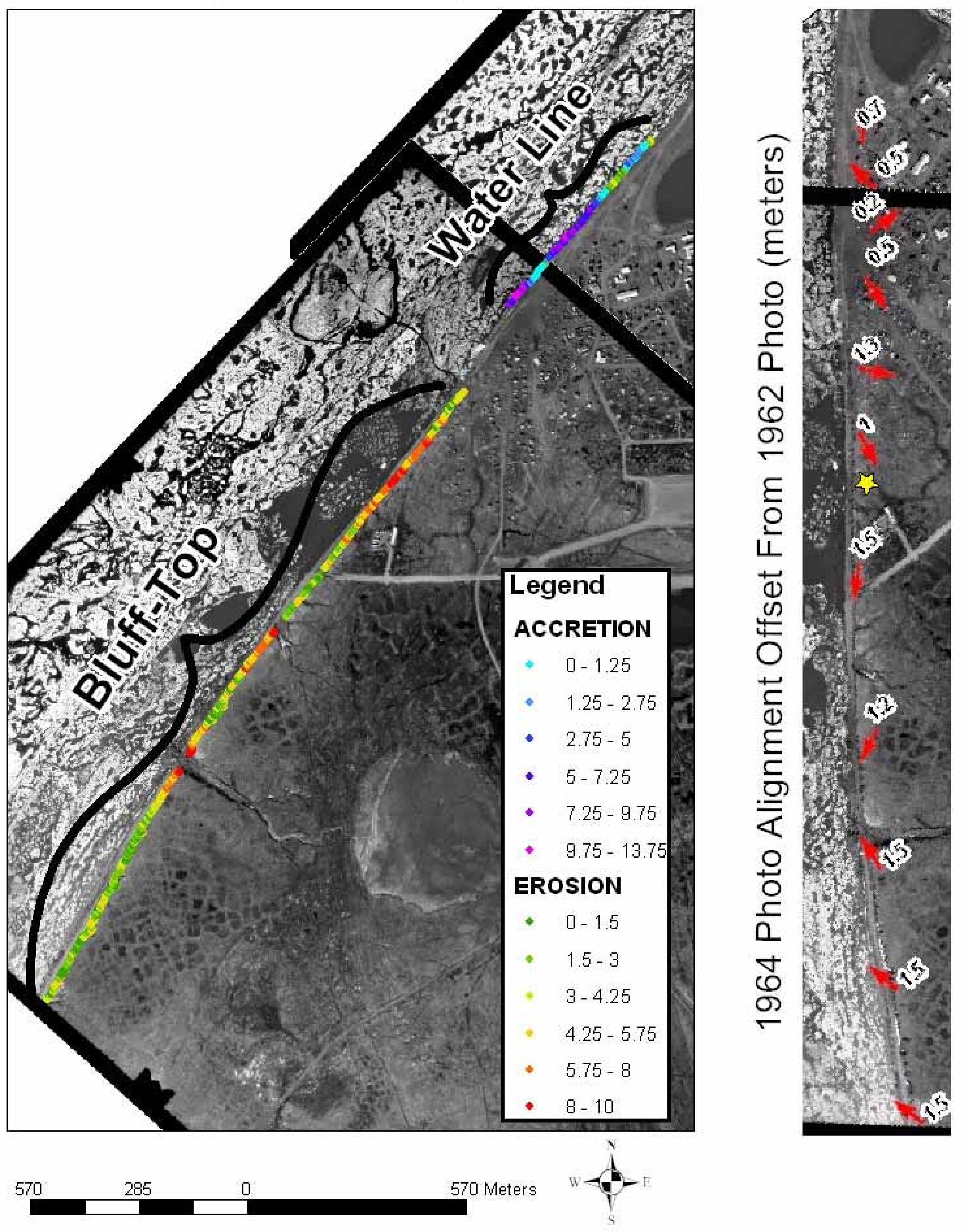

Figure 4. Barrow area coastline change between August 1962 and July 1964. The gap in measurement between the two portions is due to a gap in coverage of the 1962 photographs. The right image shows the 1962/1964 photographic alignment error (magnitude and direction) at representative points along the coast. Average photographic misalignment along this analyzed section of coast was 1 m. (Credit: P. Sturtevant.)

Hence, we have shown that the evidence does not support any linearly increasing trends in extreme westerly wind events, and the Beaufort/Chukchi cyclones that spawn them, in the Barrow area. This is despite the fact that in the Arctic as a whole, cyclones have been shown to be increasing in frequency and intensity (McCabe et al. 2001). However, the instability of the return level and the recent increases results in high uncertainty for the future. In addition, several other factors contribute to risk. Certainly, the population of Barrow and the investment in infrastructure has grown in the 40 years since the 1963 storm. There also remains an important aspect of the physical environment that dramatically enhances the potential vulnerability of the community, and that is the sea ice retreat (Figure 7). In this respect, Barrow area trends reflect the broader Arctic changes.

The increase in fetch associated with sea ice retreat has resulted in an increase in the likelihood of a damaging storm surge even if there is no increase in the frequency or severity of extreme cyclones. In addition, increased fetch results in larger waves, which controls beach modification rates and hence is important for assessing fill performance and maintenance requirements in beach nourishment activities, as well as structural requirements for hard barriers. More specifically, these interlinked environmental changes are important for the cost assessment of erosion mitigation measures, when considering the maintenance life cycle, and for budgeting emergency management requirements.

5. THE RANGE OF POLICY RESPONSES

The Barrow and Wainwright Beach Nourishment Program has been the major response so far to problems caused by coastal erosion and flooding in Barrow. Studies that led to the program were initiated after the storms of September 12 and 20, 1986. This was near the end of a decade and a half with relatively few severe storms in Barrow, and less than two years after the new utilities corridor, or "utilidor", began service to Barrow in 1984 at an initial cost of about $270 million. The Beach Nourishment Program was approved in July 1992 with appropriations for fabrication of the dredge *Qayuuttaq* and other equipment. The program was terminated in 2001 after the dredge was damaged and sunk in the (official) record storm of August 10, 2000. *Qayuuttaq* was towed to Seattle for repairs, but the North Slope Borough decided to accept an insurance settlement instead.

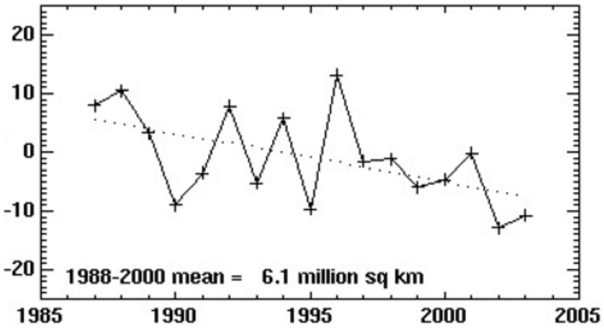

Figure 7. Change in sea ice extent over the entire Arctic during September, as estimated from passive microwave satellite imagery. The linear trend line indicates - 8.2 (+/- 7.3)% per decade. (Credit: J. Maslanik).

But the 2000 storm did not terminate further consideration of public policy responses to reduce damages from coastal erosion and flooding in Barrow. That storm prompted North Slope Borough initiation of a joint feasibility study with the U.S. Army Corps of Engineers. They are considering two alternatives, both including beach nourishment and elevation of the coastal road. But these active means of erosion mitigation are not the only ones available for reducing damages: a broader range of less visible means have been considered or implemented in Barrow, both before and after the Beach Nourishment Program. The range can be categorized as follows:

- Active erosion mitigation
- Planning, zoning and relocation
- Retrofits and new construction
- Archaeological investigations
- Emergency management

Taking into account the individual options in each of these categories, the range of informed choices is likely to be much larger than previously recognized.

The pattern of responses to coastal erosion and flooding in Barrow is distributed in the sense that different people and organizations have taken the initiative on distinguishable but overlapping parts of the overall task of reducing damages. There is no master plan that attempts to force action on a pre-determined schedule and scope of effort, nor does there appear to be the need for one. The distributed pattern allows multiple initiatives to reduce vulnerabilities to proceed concurrently rather than one at a time. It allows for relevant expertise and motivation to be brought to bear on each initiative. And it allows for coordination as necessary by individuals who have taken the lead on specific initiatives, by the Disaster Coordinator's office and the Mayor's office, and by the North Slope Borough Assembly. With each new storm that causes additional erosion and flooding, nature can be expected to reinvigorate the overall effort.

6. A NETWORKING STRATEGY

Since at least the storms of September 1986, the people of Barrow have worked as a community to reduce the vulnerability of things they value to coastal erosion and flooding arising from the confluence of extreme storms and climate change. The things of value include life and limb, public and private property, archaeological sites, and the natural environment. As part of Barrow's overall effort, it may be worthwhile to consider a strategy of networking with other Arctic coastal communities facing similar problems, and with state and federal officials in a position to provide assistance.

A networking strategy can help communities empower themselves. It is no secret that state and federal programs and agencies are not designed to solve problems of coastal erosion and flooding faced by Alaska Native villages. (Neither are corporations.) Consider for example the testimony of the representative from the Alaskan coastal town of Shishmaref at the field hearings of the Senate Appropriations Committee in Anchorage late last June. After listing more than a dozen agencies contacted by the Shishmaref coalition, Luci Eningowuk (2004) testified that "Our experience [in Shishmaref] has shown that there is a lack of continuity between the various federal and State programs and agencies…. For the most part, we have found that none of the agencies have programs that cover the full range of our needs." For solutions to these problems, it is not realistic to expect a lead program or agency with ample authorities and deep pockets to emerge anytime soon. A more realistic approach based on experience elsewhere (e.g, Cromley, in press) is for communities in a network to take the lead.

Taking the lead means working together – with outsider advisors and supporters as necessary – to adapt existing programs and decision-making structures to the needs of the communities. Local communities participating in the network can empower themselves by finding common ground on specific policy proposals backed by their own collective experience, and preferably by the best available science. From the standpoint of an elected official at a higher level, supporting such proposals is often but not always a "no-brainer" – it is an opportunity to serve some constituents without displeasing others. Finding common ground is thus one key to modifying existing state and federal policies and programs, or perhaps even creating new ones. Judging from the field hearings of the Senate Appropriations Hearings late last June, it appears that the Alaska Native villages represented there agree with GAO that benefit/cost criteria in certain programs are too restrictive. This is a step toward legislation to exempt the villages, or to relax those criteria along the lines of programs that incorporate social or environmental factors in calculating benefits (GAO 2003). Luci Eningowuk (2004) understood this: "We believe that relocation could be accomplished at a significantly reduced cost if the agencies were allowed to act under emergency exceptions, and if the agencies were not required to implement overly burdensome feasibility studies and cost benefit analysis. We are not requesting a lessening of the engineering or NEPA requirements but an approach that utilizes common sense."

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