Shishmaref Site Analysis
for
Potential Emergency Evacuation
and
Permanent Relocation Sites

completed by:

The Natural Resources Conservation Service

in cooperation with:

The Shishmaref Erosion and Relocation Coalition

NRCS

General

Shishmaref is located on Sarichef Island in the Chukchi Sea, about 120 miles North of Nome, Alaska (see Figure 1). The village is a traditional Inupiaq village with a fishing and subsistence lifestyle. The 2001 population of the village was 562 people. The island is eroding on the seaward (northwest) side. The sustained rate of erosion is reported as three to five feet per year, with severe storms causing 20 to 50 feet of erosion.

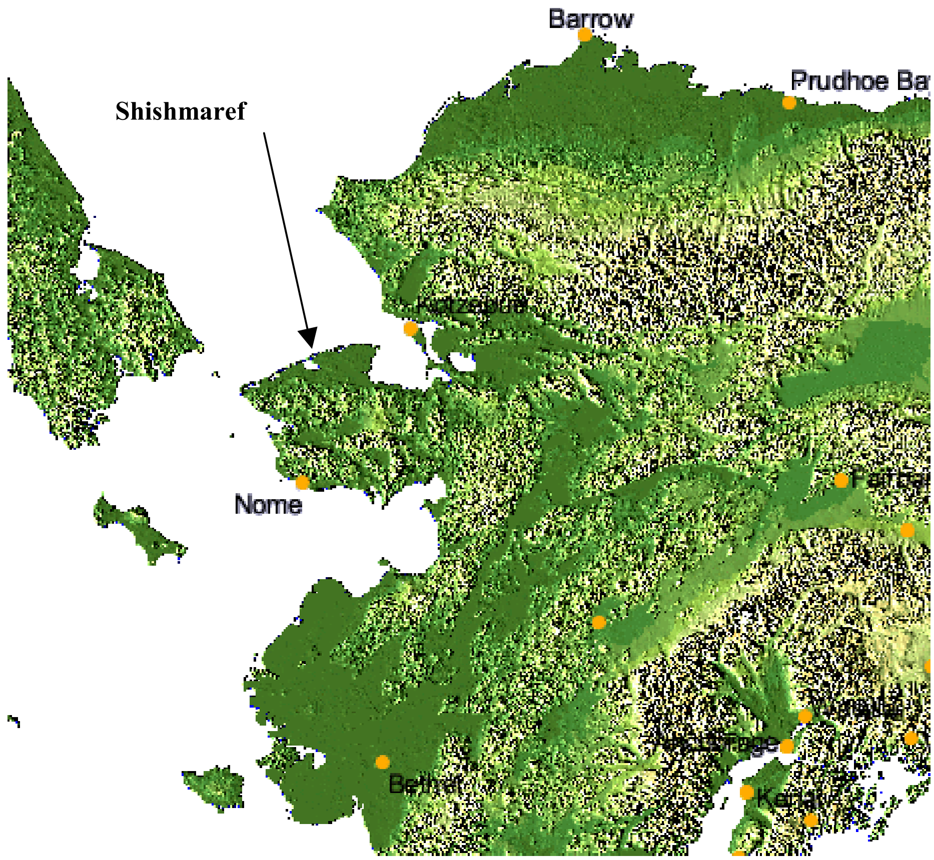

Figure 1 – Shishmaref location.

Background

Humans have inhabited Sarichef Island for at least the last 400 years. A previous townsite, Old Shishmaref Village is north of the current Village site (see Figure 2). The current Village was incorporated in 1969. On 5/21/1973, the Village Corporation passed a resolution to relocate the village because of hazards from beach erosion and flooding. During this period, the Soil Conservation Service conducted a limited soils investigation at several relocation sites. The soils reports are attached as Appendix A.

Percy Nayokpuk, who was involved in this first relocation effort, described to the NRCS team that several events caused the first relocation effort to lose momentum. First, the soils report indicated permafrost rich ground at the proposed relocation site, and at the time, this was considered a severe limitation to development. Additionally, a new school was constructed in 1977 lending an air of permanence to the Village. At this same time there were very few erosive storms.

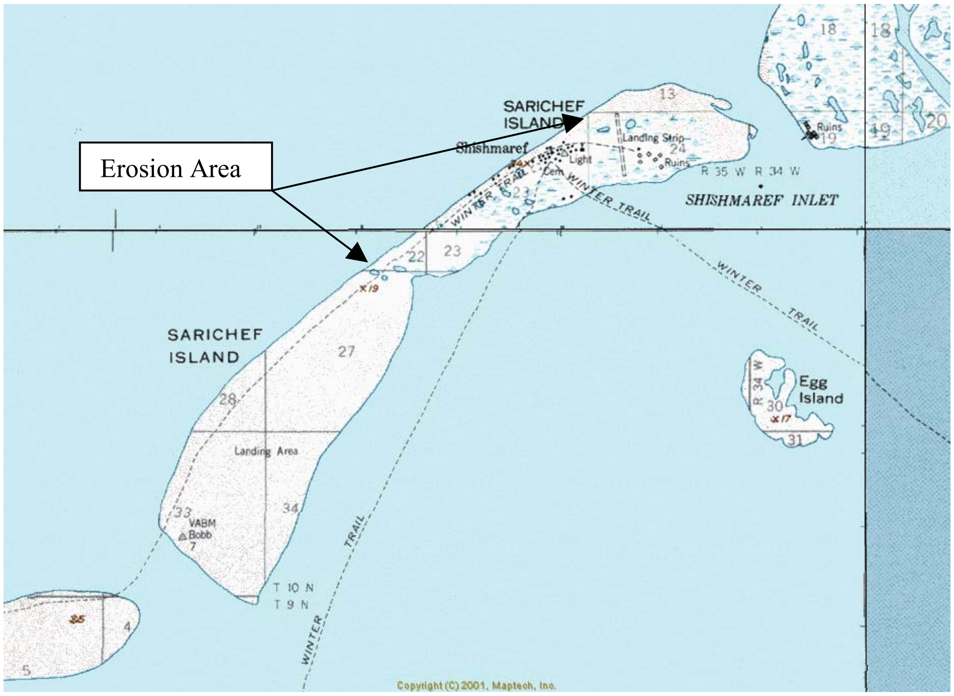

Figure 2 – Shishmaref Layout Map

Several studies were then conducted to examine alternatives for erosion control. Some of the reports include:

DOWL Engineers, 1975. *Shishmaref Erosion Protection Alternatives Feasibility and Cost Estimate*.

Petrovich and Knottingham, Inc. 1982. *Shishmaref Erosion Control Engineering Studies* for Alaska Department of Transportation.

Alaska DOT and Public Facilities, 1998. *Shishmaref, Alaska: Erosion Control Assessment*.

Several methods of erosion control have been attempted. Sand filled drums were placed on the beach as early as the 1950's. 50,000 sand bags were installed in 1974. In 1982, gabions were placed at the toe of the bluff. Shortly after, in 1984, about 1,700 feet of articulated concrete blocks were placed on the beach. In 1993, more gabions were placed against the bank. None of these approaches has provided long-term erosion control.

Recent severe storms in 1997, 2000, 2001, and 2002 have increased the rate of erosion along the seaward side of the island. This erosion caused the relocation of several houses, has exposed utility lines and destroyed roads.

NRCS visited the Village in 2001 to determine if the Emergency Watershed Protection (EWP) program could assist in treating the erosion. Due to the EWP rules prohibiting work on shorelines and on chronic problems, it was determined that NRCS could best assist the Village in other ways.

In July of 2002, the citizens of Shishmaref voted to relocate the village. NRCS assistance was requested to help evaluate emergency evacuation and permanent relocation sites. In September 2002 a team of NRCS specialists traveled to Shishmaref to provide this technical support. The team consisted of a natural resource planner, a resource soil scientist and two engineers.

Location and Setting

Sarichef Island is a one of a string of barrier islands formed along the northwest side of the Seward Peninsula. Sarichef Island is a barrier to Shishmaref Inlet. Sarichef Island is composed of sand, with a core of older sand dunes along the center of the island rising to about 25 feet above sea level. The margins around the central dunes are composed of a combination of blown in and sea deposited material. Figure 3 shows a typical barrier island cross section that is representative of Sarichef Island.

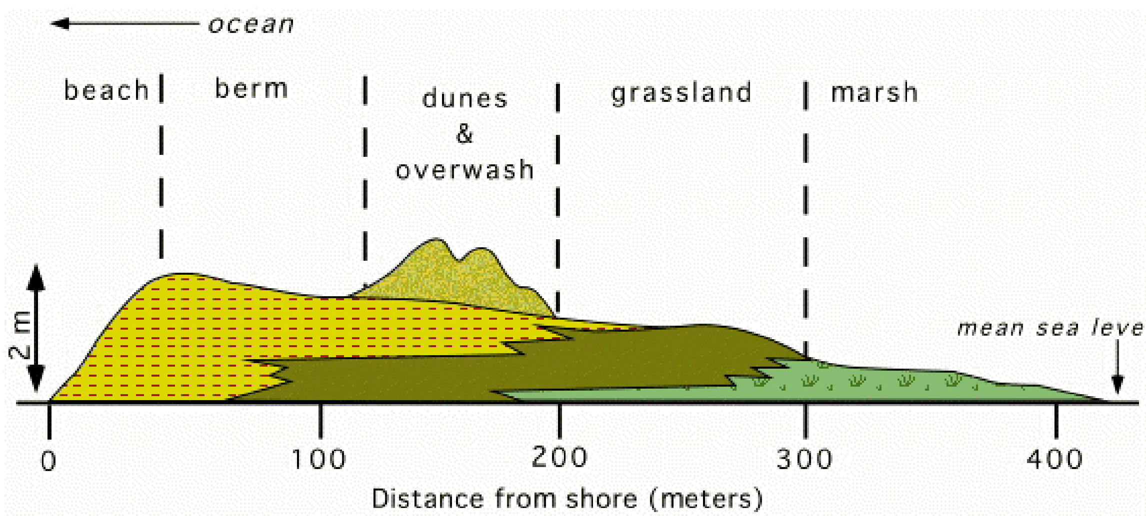

Figure 3 – Typical barrier island geomorphology.

Methods

The investigation team met with Tony Weyiouanna, Sr., Village Transportation Planner and Coordinator for the Shishmaref Erosion and Relocation Coalition (SERC). He described how the Coalition and the citizens had identified 11 areas that might have potential as emergency evacuation sites in the event of a large storm, or as permanent relocation sites. Tony provided the team with a copy of the Shishmaref Relocation Strategic Plan. The NRCS team felt they could provide technical support to:

Action Item #1: Identification of High Potential Relocation Sites
- Soil to support infrastructure requirements
- Size minimums to address community growth
- Good access by land, air and water
- Subsistence
- Develop a Site Evaluation Matrix

Action Item #2: Identify the Required Evaluations and Studies
- National Environmental Policy Act
- Geotechnical Studies
- Hydrologic Studies
- Other

In addition to examining the sites to assess relocation potential, the NRCS team was also asked to assess the sites for potential as emergency evacuation sites. The thought is that during a severe storm, if the entire town is threatened, there should be an identified evacuation location.

Of the 11 areas identified, the Coalition and the citizens selected the five most likely sites and broadly represented these with 5 to 10 square mile blocks drawn on maps. These are shown in Figure 4.

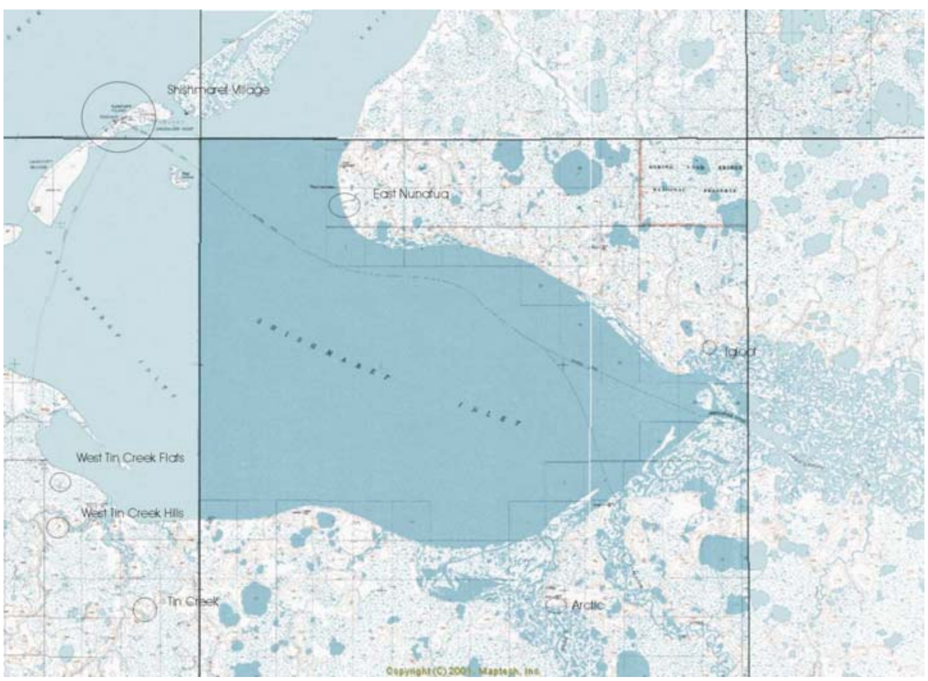

Figure 4 – Potential relocation sites.

The team then selected the order of the site investigation. Using US Geological Survey topographic maps, specific investigation areas were selected from the larger locations. These areas were selected to be:

- Greater than 50 feet above sea level in order to limit storm surge flooding
- Flatter than 10% slope to facilitate development
- Contiguous area of more than 100 acres that meets the first two criteria

Tony Weyiouanna, Sr., Stan Tocktoo, and Harold Olanna piloted the boats, and answered the team's questions about the resources and natural history of the areas. The team selected the locations to examine more thoroughly, including augering holes in the soil, describing the vegetation, and acquiring GPS points and photographs. The broader areas examined as well as the particular soil sample sites are shown in Appendix B.

Site Descriptions

East Nunatuq

East Nunatuq is 6.4 miles east by southeast of Shishmaref. The site has gently rolling hills with perennial streams and lakes nearby. The ground is generally south facing with an average elevation of 75 feet. Soils are 6 to 12 inches of vegetative mat, and then 12 to 16 inches of gray silt to ice at maximum thaw. East Nunatuq has direct access to Shishmaref Inlet. The bay area is shallow.

Figure 5 – East Nunatuq site.

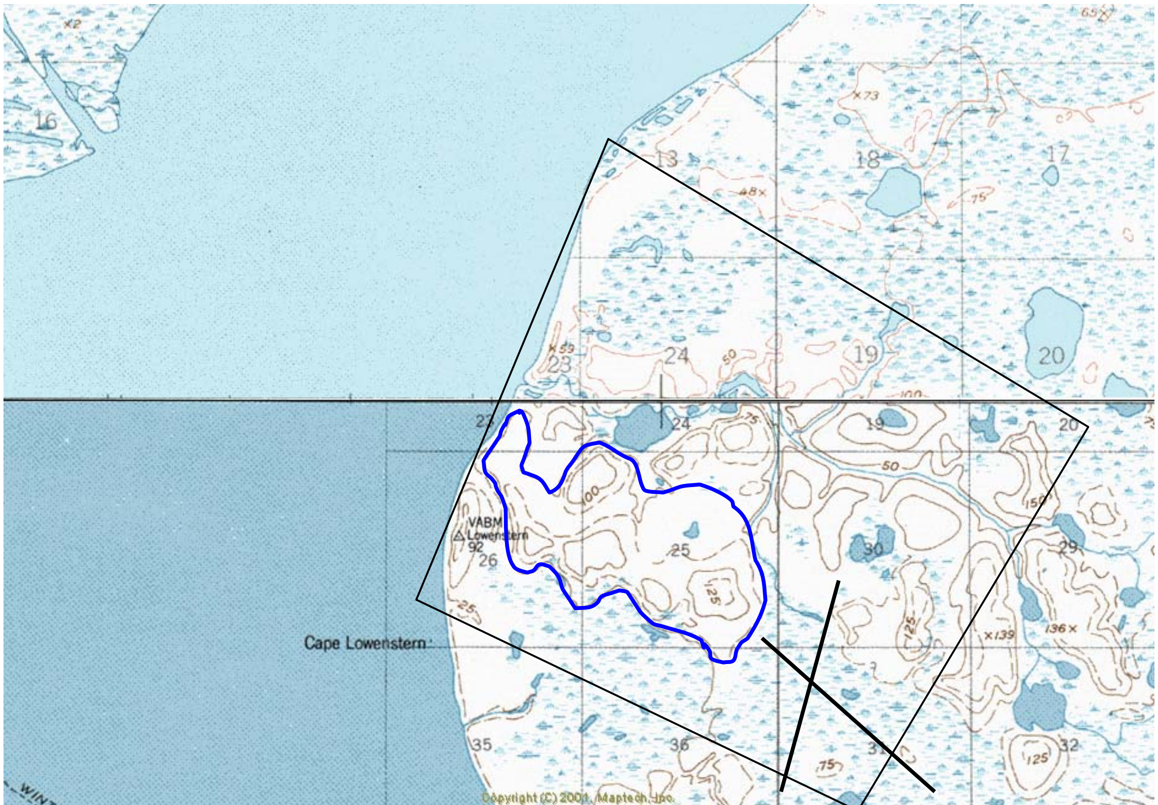

Figure 6 – East Nunatuq location map. Blue outline is the site investigated for the village. Dark black lines are a possible airstrip alignment. Light black lines encompass the original investigation area.

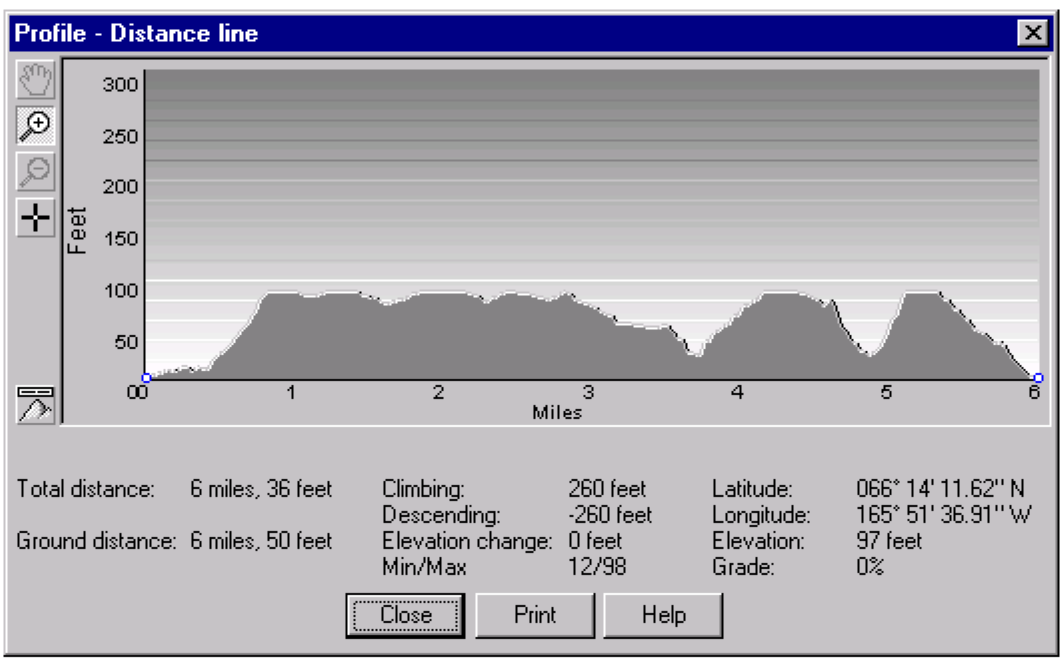

Figure 7 – East Nunatuq perimeter profile. The perimeter profile graphically shows the elevation differential around the boundary of the site investigated for the village.

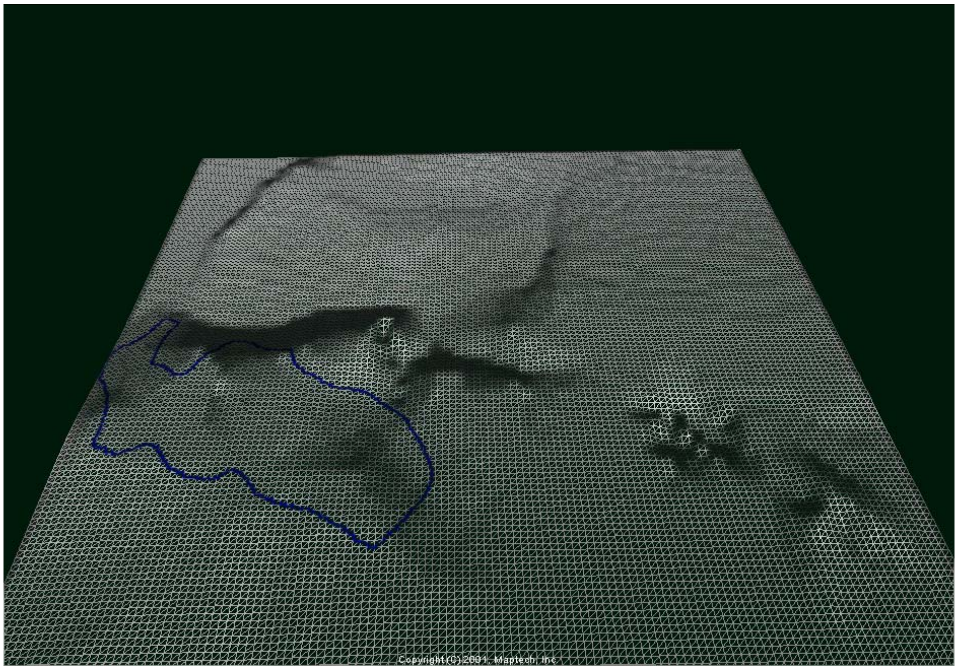

Figure 8 – East Nunatuq wire frame model.

Arctic

The Arctic site is accessed by boating about two miles up the Arctic River. The site is located 16.4 miles southeast of Shishmaref, and is bounded by the Sanaguich and Arctic Rivers. The terrain is nearly flat to gently sloping. Underneath a foot of vegetative mat, soils are gray silt 12 to 16 inches deep to permafrost. The harbor area is shallow and requires careful navigation to find the entrance to the river. The river may not provide enough space for a small boat harbor. To use Shishmaref Inlet for a harbor, an access road would be needed from the town site.

Figure 9 – Arctic Site (on top of hill) looking from the Arctic River.

A location map, perimeter profile, and wire-frame model of the Arctic site, as well as the remaining sites, are located in Appendix B.

Igloot

The Igloot site has rolling terrain and moderate slopes, and is 15.9 miles from Shishmaref. The Igloot site is near the Serpentine River, and is very near some fish camp cabins and some archaeological sites. Igloot offers a fairly direct access to Shishmaref Inlet. Compared to the other sites the soils are slightly deeper (24”) and coarser (fine sand compared to silt).

Figure 10 – Igloot site.

Tin Creek

The Tin Creek site is long and narrow, and is dissected by some drainages. The Tin Creek site is accessed through a south branch of Tin Creek, and it is bounded on the east by Goose Creek. The Tin Creek site is 11.6 miles from Shishmaref. Soils are 12 to 16 inches of gray silt down to permafrost. The Tin Creek site would require a 2-mile access road to reach the Inlet where a small boat harbor and barge access would be located. The Tin Creek site is closest to the gravel source at Ear Mountain.

Figure 11 – Tin Creek site.

West Tin Creek Hills

West Tin Creek Hills is the smallest, most compact site. Terrain is flat to gently rolling, and the soils are 12 to 16 inches of gray silt to permafrost. The site is accessed by boating about two miles up the main stem of Tin Creek. Like Tin Creek, this site would require an access road to the inlet. West Tin Creek Hills is close to several lakes.

Figure 12 – Soils investigation at West Tin Creek Hills.

West Tin Creek Flats

This site is on very flat ground adjacent to the Inlet. Soils are gray silt 8 to 12 inches to permafrost. This site would be easy to develop due to the topography, but drainage is a concern. There are indicators of massive ice formations at this site, such as solifluction and polygons.

Figure 13 – West Tin Creek Flats.

Site Evaluation

The relocation sites were rated by professional judgment of the quality of the soil, water, and plant resources, as well as human factors. Similarly, the soil, water, plant and human factors were assessed to determine if development of a village would cause them harm. Often, a qualitative descriptor such as *poor* or *good* was used to describe the natural resources. These descriptors are most useful when compared to each other within the same category. Compared across categories (such as *site location* compared to *infrastructure*) these qualitative words may lose meaning.

To arrive at an overall ranking within a category, the ratings for all the factors in that category were combined. Each factor within a category was weighted equally for this exercise. This assumption should be considered by the community. For example, it would be equally valid to rate the proximity to water sources twice as important as potential for erosion if the community wished.

There are some assessments that are very preliminary and cursory. The analysis about fresh water sources, and all of the factors in the Infrastructure category need a great deal more analysis.

Site Evaluation Factors

Site Layout

The general layout of a site was measured in three ways. The size of the flat area was determined from maps and reported in acres. The mean elevation of the site was logged with an altimeter, and in general, a higher elevation received a higher score. The layout of the ground was ranked qualitatively. Compact, circular layouts with no dissection received higher scores while long and narrow arrangements received lower ones.

Development Potential

The ease of site development was examined in several ways. The average slope of the land and the overall quality of the soils was ranked. A moderate slope of 2 to 6% was rated higher than a flat slope, or a steep slope. Soil that was deeper to permafrost was ranked higher, and coarser soil was ranked higher than finer grained soil.

The drainage of the site was ranked qualitatively. Potholes and bogs were rated lower. Long, gentle, undissected slopes were ranked higher.

Proximity to material sources was ranked by observation, and each site was ranked for its proximity to a site for sand, for gravel, and for rock.

Natural Resources

The sites were examined for natural resource advantages and disadvantages. Fresh water sources were examined and categorized by type. The types examined were Lakes, Springs, Rivers and Potential Groundwater sources. A site was rated high if it had several different kinds of water resources.

The locations were examined for erosion and flooding potential. These were rated qualitatively low, medium and high. Since by definition the sites were located above 50 feet elevation, flooding hazard from the ocean was low at all sites.

The availability and proximity of subsistence gathering, hunting and fishing areas was discussed. The team elected to not analyze this factor. It was decided to gather more input from the citizens regarding subsistence aspects of each site.

Infrastructure

The sites were rated qualitatively as poor, fair or good for their potential for an airport. The team looked for sites that were relatively flat, and could support a primary runway and a cross-wind runway of about 5,000 feet in length. This location was then examined for its proximity to the village site.

Similarly, the sites were rated as poor, fair, and good for a location to build a small boat harbor and marina. Considerations included space, water of medium depth, ease of access from the village site, and an estimate of development cost.

Each site was rated qualitatively for its ability to handle large barge traffic. Factors included depth of approach channel, location of unloading facilities and proximity to the town site.

Locations for a sewage lagoon, a landfill, and a variety of access roads were examined. Considerations such as proximity to the fresh water supply, land slope, and distance from the town site were considered.

Human Factors

Several human factors were discussed. These included the impact of development at a site to Native Allotments, and to cultural resource sites. The team decided to defer this analysis, and its weighting in the overall decision, to the community.

The team determined that there were some factors, such as aspect and aesthetics, that were difficult to rank even in a qualitative sense. To that end, the team provided a single ranking category for miscellaneous factors, and each team member was polled about these.

Emergency Relocation

During the investigation, the team discussed various factors that would distinguish one site from another as a good emergency relocation area. In order for any of these undeveloped sites to be a reliable place to go during a storm, they would need at least a boat landing, shelter, potable water and emergency rations. Access to a site is among the top concerns if it is to be used for emergency evacuation.

However, in the event of an emergency, it may not be physically possible or timely to evacuate people from Sarichef Island. Considering this factor, the team feels that true emergency evacuation areas should be located on Sarichef Island (for example, in the school or the church). Also, because of this factor, the team felt it was best to not make any recommendations about emergency relocation sites off the island. If the community wishes to create an emergency relocation site that is not on or near Sarichef Island, these data presented to support a permanent relocation area may help.

Results

Site Layout

West Tin Creek Flats had the largest potential development area, and also the largest contiguous area of acceptable ground. It also had the lowest elevation of any site we investigated. West Tin Creek Hills had the best combination of shape, elevation and area, followed closely by Igloot and Arctic. The relative rankings are shown in Figure 14, and the tabular data for the site layout rankings are shown in Table 1.

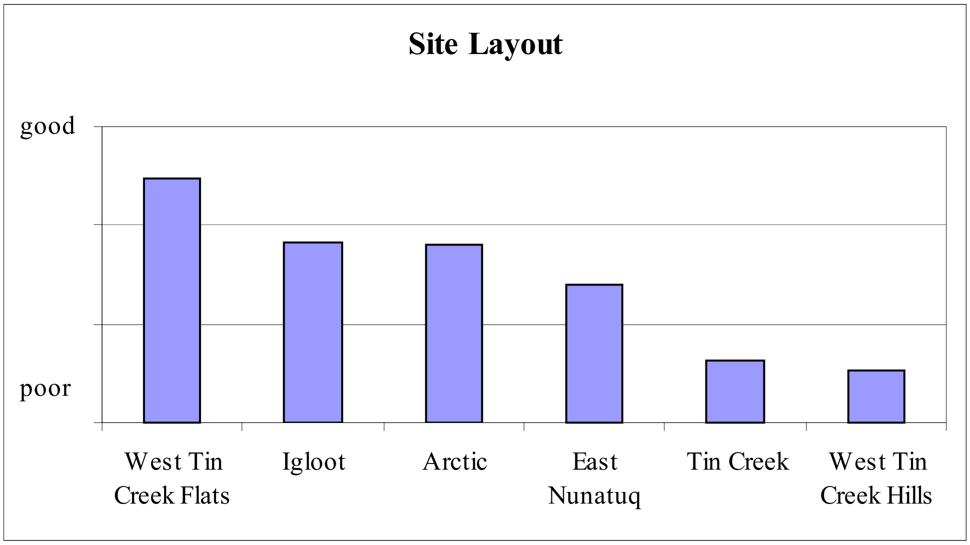

Figure 14 – Site Layout relative rankings.

Site	**Area** acres	**Elevation** feet	**Contiguous Ground**
East Nunatuq	520	75	Low
Arctic	340	100	Medium
Igloot	450	75	Medium
Tin Creek	390	50	Low
West Tin Creek Hills	160	50	Medium
West Tin Creek Flats	640	25	High

Table 1 – Site layout data.

Development Potential

Most of the sites were a similar distance from building materials. A slight advantage was given to the sites on the southwest side of Shishmaref Inlet, as they are closer to Ear Mountain, a source of rock and gravel (see Figure 16). A large sand deposit behind a barrier island is available near West Tin Creek Flats. A slightly thicker thawed layer was discovered at both Igloot and West Tin Creek Hills than at the other sites. The West Tin Creek Flats site was rated poor for drainage due to the flat slope and the presence of massive ice.

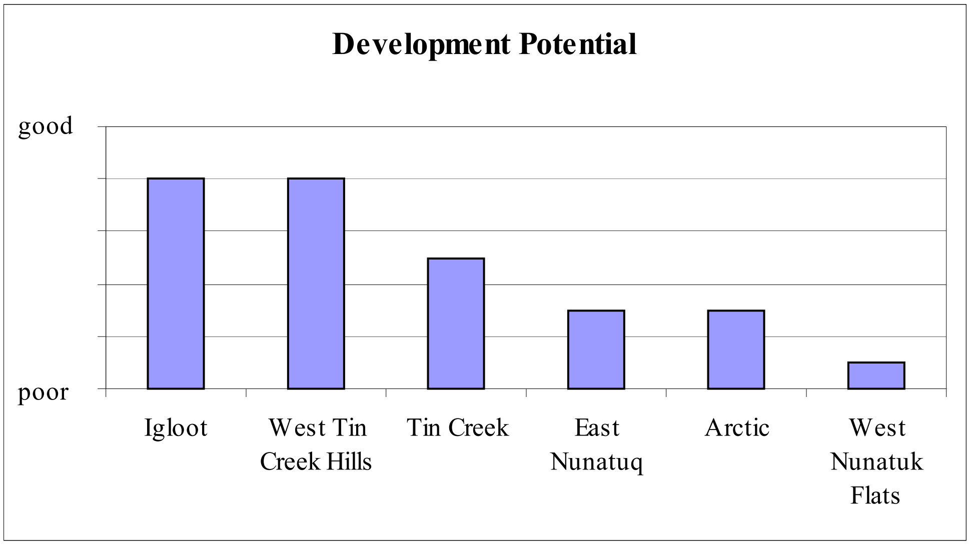

Figure 15 – Development potential relative ratings.

Site	Slope	Soils	Drainage	Materials Source		
	percent			sand	gravel	rock
East Nunatuq	6	Fair	Fair	Poor	Poor	Poor
Arctic	2	Fair	Fair	Poor	Poor	Poor
Igloot	4	Good	Good	Poor	Poor	Poor
Tin Creek	6	Fair	Fair	Fair	Fair	Fair
West Tin Creek Hills	4	Good	Fair	Fair	Fair	Fair
West Tin Creek Flats	1	Poor	Poor	Good	Fair	Fair

Table 2 – Development potential data.


Figure 16 – Ear Mountain as seen from Tin Creek.

Natural Resources

The tabular information for the Natural Resources attributes are shown in Table 3 and the subsequent ratings are displayed graphically in Figure 17. None of the sites had any particular hazards from erosion, and none had flooding hazards. This was primarily because the selected sites were away from the ocean. There was some concern about streambank erosion, particularly at Igloot, Tin Creek, and West Tin Creek Hills. Streambank erosion will surely be a problem at these sites if there is a great deal of boat traffic up and down the adjacent streams.

Igloot and Tin Creek rated the highest in the Natural Resources category due to having many potential sources of water. West Tin Creek Flats rated low because of fewer fresh water sources and potential for bluff erosion.

Site	Fresh Water[1]	Subsistence[2]	Erosion
East Nunatuq	L		Low-Medium[3]
Arctic	S,L,G		Low-Medium[3]
Igloot	R,L,S,G		Low-Medium[4]
Tin Creek	S,L,R,G		Low-Medium[4]
West Tin Creek Hills	S,L,G		Low-Medium[4]
West Tin Creek Flats	S,L,G		Medium-High[3]

[1] S = Spring, L = Lake, R = River, G = Suspected Groundwater

[2] The team did rate the site's quality for subsistence

[3] Bluff erosion potential

[4] Streambank erosion potential

Table 3 – Natural resources attributes.

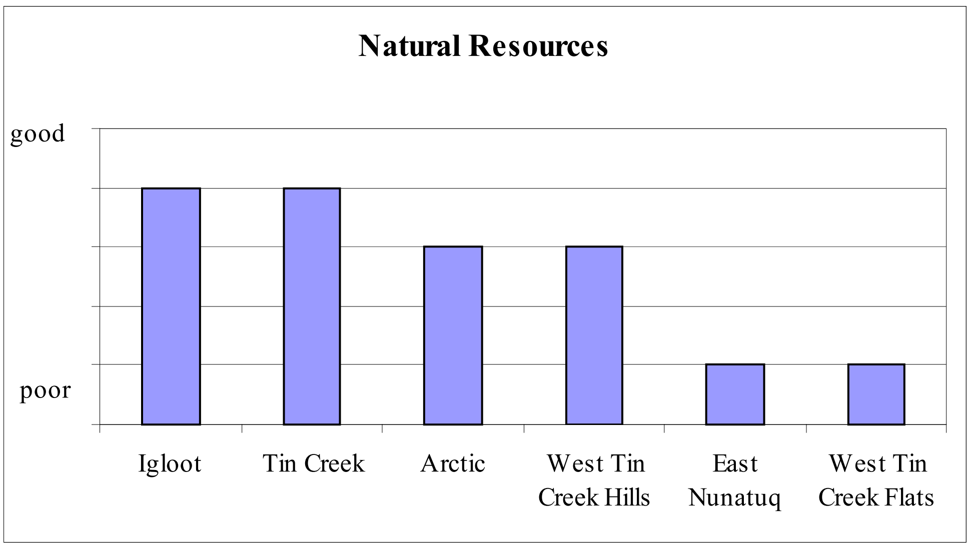

Figure 17 – Results of natural resources rankings.

Infrastructure

Most of the sites investigated will require some sort of access roads. These roads were divided into Local access roads, those between major parts of the town, and Service roads going to the airport, marina, etc… Because the investigation sites were selected for gentle terrain, road construction should not be difficult with the correct construction materials.

Similarly, most locations should allow easy airport development. In most cases the airport will be built where there is poor drainage. This is due to the large area of contiguous land required for construction.

Because soils and topography were similar between the sites, the difficulty of building landfill and sewer lagoons is similar. West Tin Creek Flats was rated poor due to drainage considerations and the Tin Creek Sites will be more difficult construction areas for lagoons due to the dissected nature of the area.

Site	Airport	Small Boat Harbor	Barge Access	Sewage Lagoon	Landfill	Access Road Local	Access Road Service
East Nunatuq	Fair	Poor[1]	Poor	Fair	Fair	Fair	.75 mi
Arctic	Fair	Fair[2]	Poor[3]	Fair	Fair	Fair	2.5 mi [5]
Igloot	Poor	Poor[1]	Fair	Fair	Fair	Fair	1 mi
Tin Creek	Fair-Good	Fair[2]	Fair[4]	Poor	Fair	Fair	2 mi
West Tin Creek Hills	Fair	Fair[2]	Fair[4]	Poor	Fair	Fair	1.5 mi [5]
West Tin Creek Flats	Good	Fair-Good	Fair[4]	Poor	Poor	Poor	0 mi

[1] A constructed breakwater will be required
[2] A constructed port and marina will be required
[3] This site will need a long jetty and constant dredging
[4] These ports are well sheltered. A jetty will be required
[5] Bridges will be needed on the road to the harbor

Table 4 – Infrastructure development data.

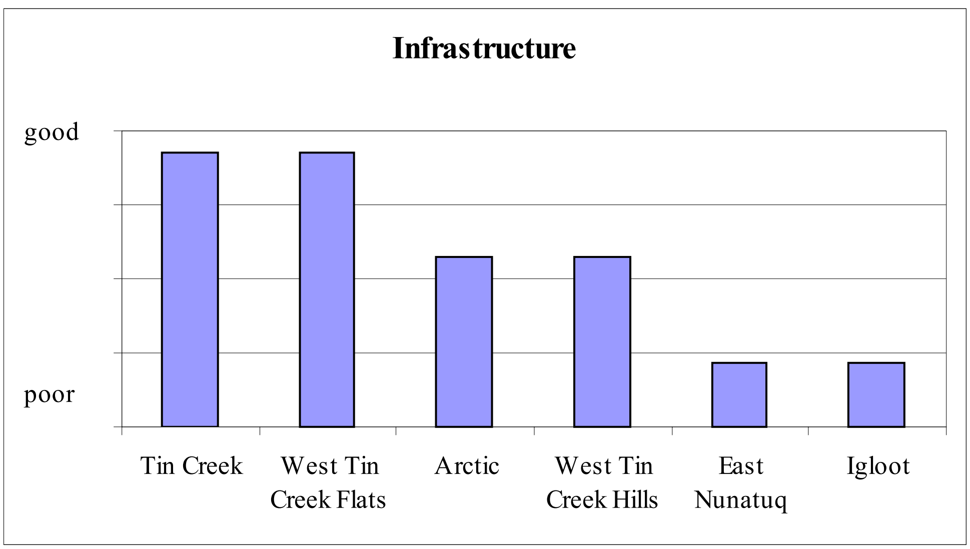

Figure 18 – Infrastructure development relative ratings.

Social and Cultural Considerations

The team did not analyze information that pertained more to the social and cultural aspects of relocation. However, these aspects were discussed and it was decided the local community would need to agree on their relative ranking, and on their relative weighting. The team did work to capture their own ‘gut’ feeling about the relocation sites, and this is shown in Table 5.

Site	Cultural Sites	Native Allotments	Team Consensus
East Nunatuq			Low
Arctic			Medium
Igloot			Medium
Tin Creek			High
West Tin Creek Hills			High
West Tin Creek Flats			Low

Table 5 – Social and Cultural considerations data.

Overall Ratings

By examining the relative score of each site from a Physiographic, Infrastructure, Natural Resources, Development and Social perspective, an overall rating can be given to a site. This required a relative weighting between the five categories, and the team decided to give all categories equal weight. This judgment requires review by the community. For example, the community may wish to weight Social and Cultural factors twice as heavily as they rate Site Development factors. Changing this weighting may change the overall site ranking.

Similarly, the community needs to carefully review the relative rankings the team gave each of the components. Because of the arbitrary break between poor and fair, for instance, there should be a good deal of debate before these results are declared final.

The site at Igloot is the most desirable site using the methods and weightings described above. West Tin Creek Hills and Tin Creek were second and equally desirable while Arctic is less so, as shown in Figure 19.

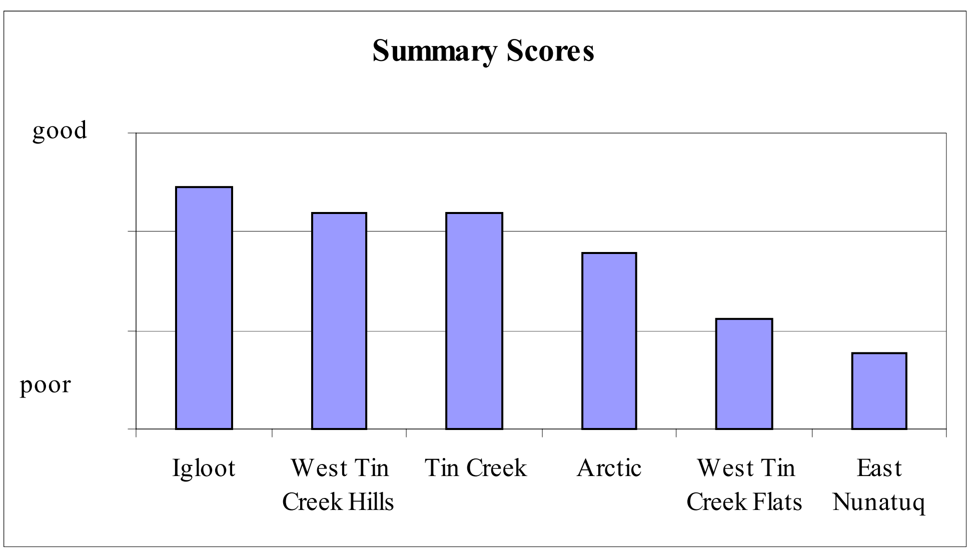

Figure 19 – Overall relative site rankings.

Next Steps
Review this information. The community and the Coalition should review this report, ask questions, and suggest improvements. Specifically, the community should comment on the Social and Cultural factors that are different between the sites. The community should also discuss the relative importance of the five ratings categories, and the relative importance of factors within each category.

The Coalition and community need to decide that all the potential relocation sites have been examined. We should not move beyond this scoping process until everyone is satisfied that all potential sites have been examined.

If the Coalition and the community can agree on the assessment presented in this report, more thorough site investigations should be conducted. These site investigations should include a thorough examination of aerial photography. All available satellite images should be gathered and analyzed.

Existing elevation surveys should be examined and supplemented if need be. These surveys can be used to create a digital elevational model (DEM) and this can be used for a wide variety of planning and analysis applications.

Soils and vegetation of the selected site should be mapped more closely. Similarly, runoff and stream channels should be mapped, and assessed for stability.

Water quality of the surface waters should be measured and characterized. Constituents such as dissolved solids, suspended solids and coliform bacteria should be measured.

Potential sites for a landfill, a sewer lagoon, an airport runway and access roads should be identified by community members. Natural resource, village safe water, and transportation planning professionals should provide guidance. Location of these important features will allow for more extensive testing of soils and permafrost to determine special design considerations.

Conclusions
This report describes the methods and results from a team of technical specialists examining 6 relocation sites over a period of a week. The findings are based on best professional judgment, and a limited amount of measurements. The community should closely examine the assumptions and findings of the team, to determine if they agree with them.

NRCS appreciates the opportunity to work with the Coalition and village. If the community approves of the work NRCS has done for them, NRCS is available to do a more detailed investigation once the community has narrowed their selection to one or two sites.

Appendix A
Original Soils Investigation, 1974

SUMMARY OF MEETING ON RELOCATION OF SHISHMAREF, ALASKA

On January 14, 1974, a meeting was held in the conference room of the Soil Conservation Service in Anchor , Alaska, to discuss interest and assistance available for the relocation of Shishmaref, Alaska, to the mainland. The following were in attendance:

Percy K. Nayokpuk - Public Service Aide, Shishmaref, Alaska

James E. Moody - State of Alaska, Department of Public Works, Division of Aviation, Chief Planning Engineer

Richard E. Downing - State of Alaska, Department of Public Works, Division of Aviation, Assistant Planning Engineer

Mike Navvaro - District Engineer for the Public Health Service

Dr. Sam Rieger - State Soil Scientist for the Soil Conservation Service

Weymeth E. Long - State Conservationist for the Soil Conservation Service

Mr. Nayokpuk gave the group a brief resume of the villagers' viewpoints for relocating their village. He discussed the present location, what problems are being encountered at their existing location that requires the relocation, and their proposed relocation site on the mainland. The problems encountered with the old village centered primarily around storm damage and the general erroding of the spit. The cost to resolve this damage and remain on the spit would apparently far exceed that of relocating the village. The relocation site would be approximately six miles from the present village of Shishmaref. It would be on higher laying land across the bay from the spit on which Shishmaref is located. The proposed site would still require hauling of water as the available water supply is still three or four miles distance from the relocation site. There would appear to be limited opportunities for developing water in the immediate adjoining area to the village.

Mr. Nayokpuk and the villagers are concerned about locating a site on land best suited from a standpoint of construction damages to improvements that could be encountered due to permafrost, sanitary needs, and other considerations which must be considered when relocating or building a community in the northern latitudes.

The representatives of the Department of Public Works, Division of Aviation, gave a brief resume of the minimum requirements for installing a new airport and an approximation of the general costs that could be anticipated if this were done today or in the immediate future. Mr. Navvaro discussed at length various aspects which the Department of Public Health would be concerned and that the village should consider in its relocation. Dr. Rieger pointed out, in turn, what assistance we could provide in terms of a detailed soil survey for use by others in planning and developing the new community. To provide the best survey data, Dr. Rieger stressed the need to make the survey as late as possible yet prior to freeze-up. This would permit identifying those areas with the least permafrost problem as well as permitting us to do the most comprehensive investigation in the light of all of the considerations when relocating a village.

It was agreed by everyone that it was important to get the best possible location for the relocation of Shishmaref. However, as it was pointed out by Mr. Nayokpuk its physical location is rather limited by the area of land available for the relocation. The land for relocation would be that controlled or that will be received by the village. It is surrounded by a proposed National Refuge that is restrictive in the amount of available land. Also, the limitation of having to have access via water limits the location on the mainland. The village must be near a channel that would provide the villagers access to the ocean.

It was agreed, if possible, that a field trip involving the various agencies and village leaders would be desirable. Then everyone could examine the proposed site and based on soils, physical properties and other needs could determine in the field the best location.

It would take as a minimum probably two weeks in the field to completely map the soils of an area adequate for a village. At the time this mapping is done, the samples would be taken so that tests could be run on the various materials for the various agency needs in designing and planning their related facilities. The possibility of acquiring a drill rig to take some deeper samples was discussed. If this were possible, it would greatly facilitate the survey as well as provide more data on the lands or soils underlying the proposed relocation sites. Mr. Nayokpuk was going to check on this as there was a rotary rig currently working in the village. Its availability either in the immediate future or during the summer at some future date was unknown. It was expressed, however, that if it were available, it would probably have to be used during the winter months which would actually limit its use from the standpoint of the soils survey.

It was agreed that the coordination would center around Mr. Nayokpuk with the various parties working through to him so that he could carry out this responsibility. Once the team got to the village, then it would be necessary that facilities for one to two weeks be made available for the staff carrying out the investigation. Mr. Nayokpuk thought that this could be accomplsihed as there appeared to be some type of guest house where arrangements could be made for this purpose. This concluded the meeting.

SOILS REPORT

Ikpek and Shishmaref Areas

The soils at Ikpek and Shishmaref are very similar. The soils in the old beach ridges and sand dunes are well drained medium and fine sand with permafrost usually below a depth of 4 feet. The soils in the intervening swales are are very poorly drained sand with a thick surface mat of living plant roots and decaying plant material. The surface mat is normally 7 to 16 inches in thickness but in places more than 40 inches in thickness. Permafrost in the very poorly drained soils is usually at a depth of less than 2 feet during periods of maximum thaw.

The well drained sandy soils are generally well adapted for location of foundations for low buildings, streets and roads, and some other city facilities. However, pre-construction investigation is necessary to locate possible ice-rich areas.

SOILS REPORT

Nunatak and Singeak Areas

The soils of the Nunatak and Singeak areas are similar. They are poorly drained silty soils with permafrost. These soils have a surface mat of living plant roots and decaying plant materials. The surface mat varies from 8 to 14 inches in thickness. The underlying mineral material is silty and has a nearly neutral reaction. Permafrost occurs at a depth of less than 12 inches below the mineral surface during periods of maximum summer thaw. These frozen soils probably contain 40 to 70 percent water in the form of ice-wedges, ice-lenses, and thin bands of ice.

Use of these soils for location of foundations for low buildings, streets and roads, sewage disposal systems, and other city facilities would involve the management of the permafrost. Changes to the surface mat resulting from construction will alter the heat transfer regime to the soil. Controlling thawing of these soils resulting from surface alterations would become complicated and probably very expensive.

Appendix B
Location and Topographic Maps

Figure B1 – East Nunatuq Soil Pit Locations.

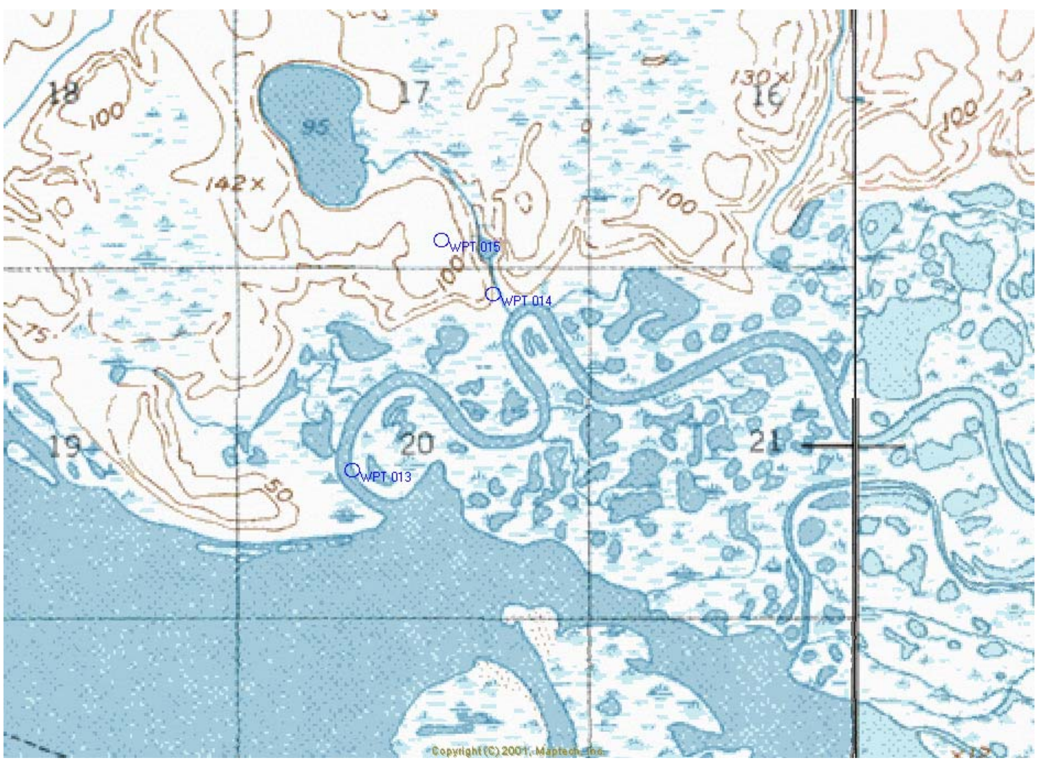

Figure B2 – Igloot Soil Pit Locations.

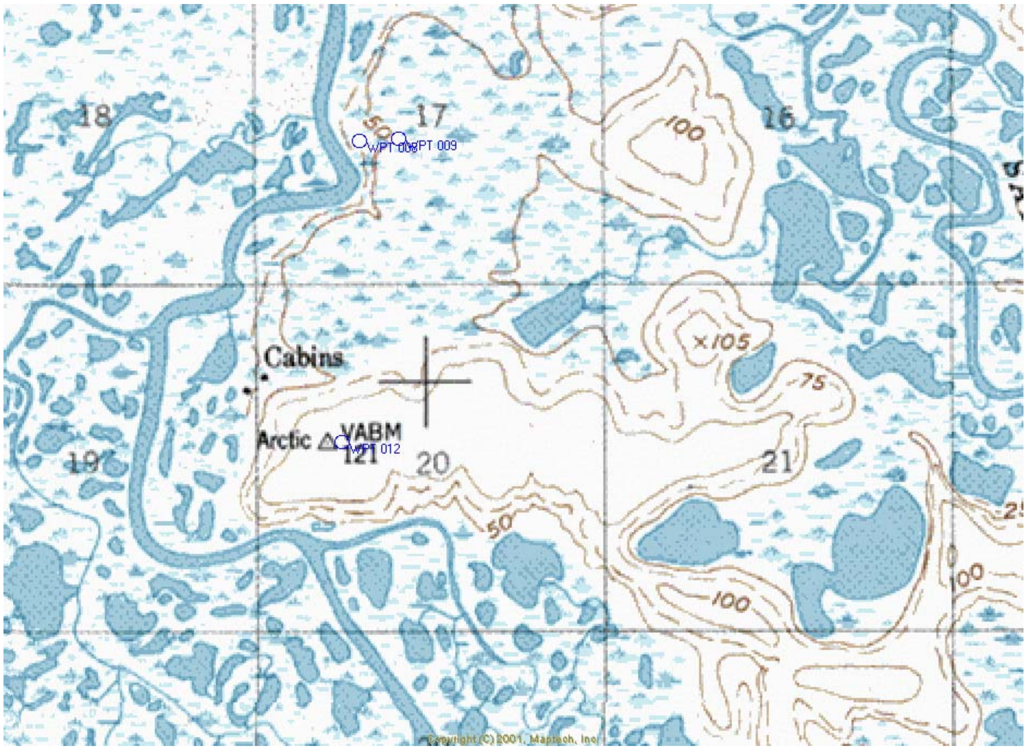

Figure B3 – Arctic Soil Pit Locations.

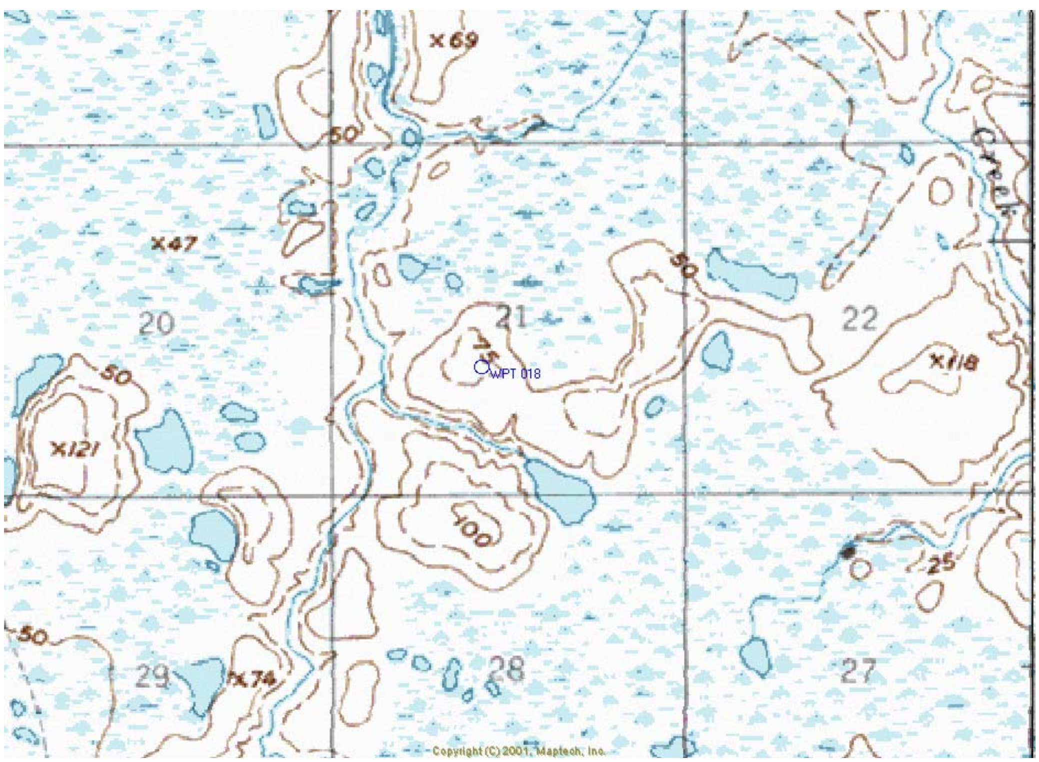

Figure B4 – Tin Creek Soil Pit Locations.

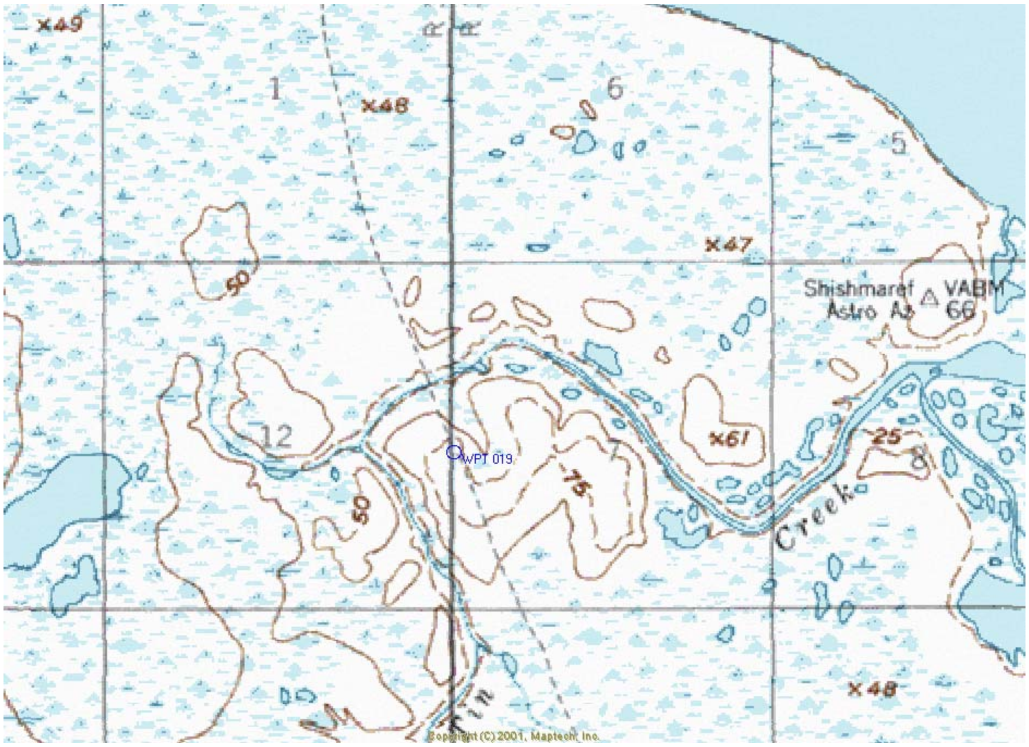

Figure B5 – West Tin Creek Hills Soil Pit Locations.

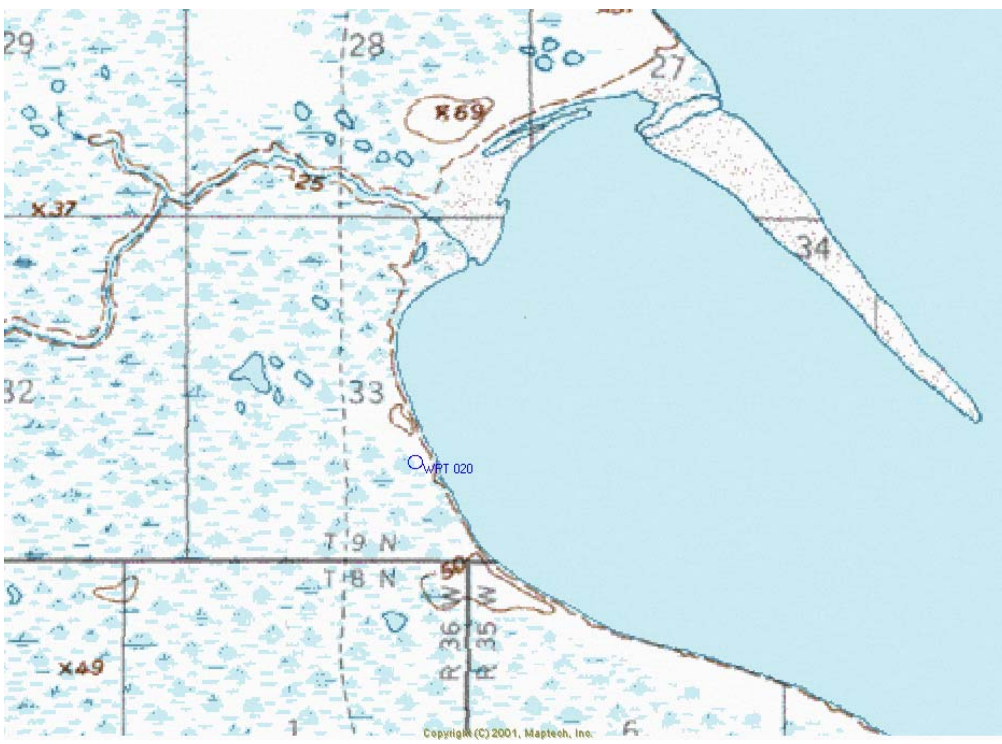

Figure B6 – West Tin Creek Flats Soil Pit Locations.

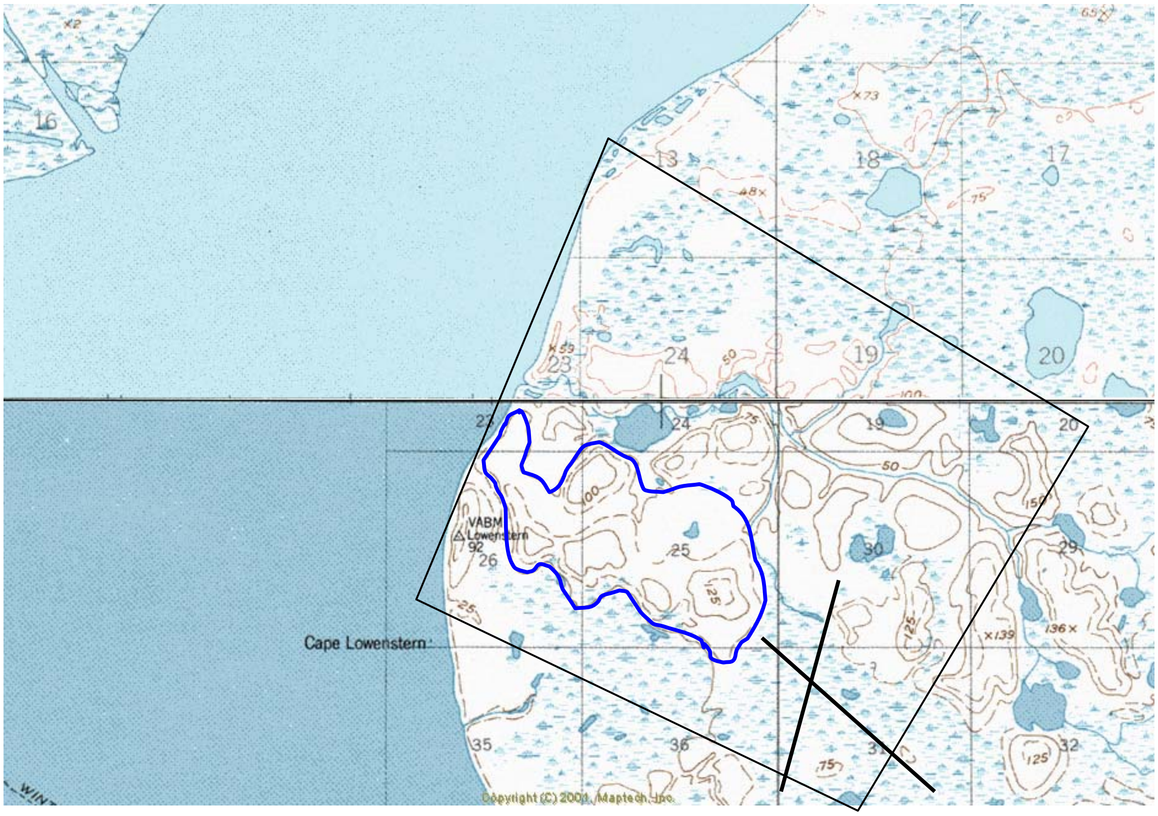

Figure B7 – East Nunatuq location map. Blue outline is the site investigated for the village. Dark black lines are a possible airstrip alignment. Light black lines encompass the original investigation area.

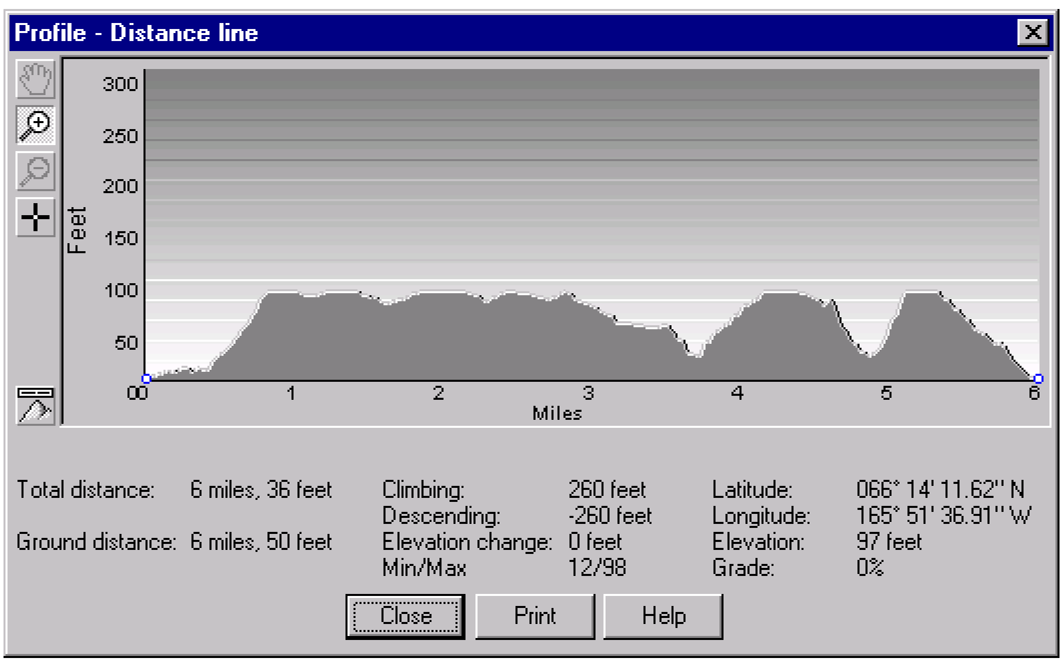

Figure B8 – East Nunatuq perimeter profile.

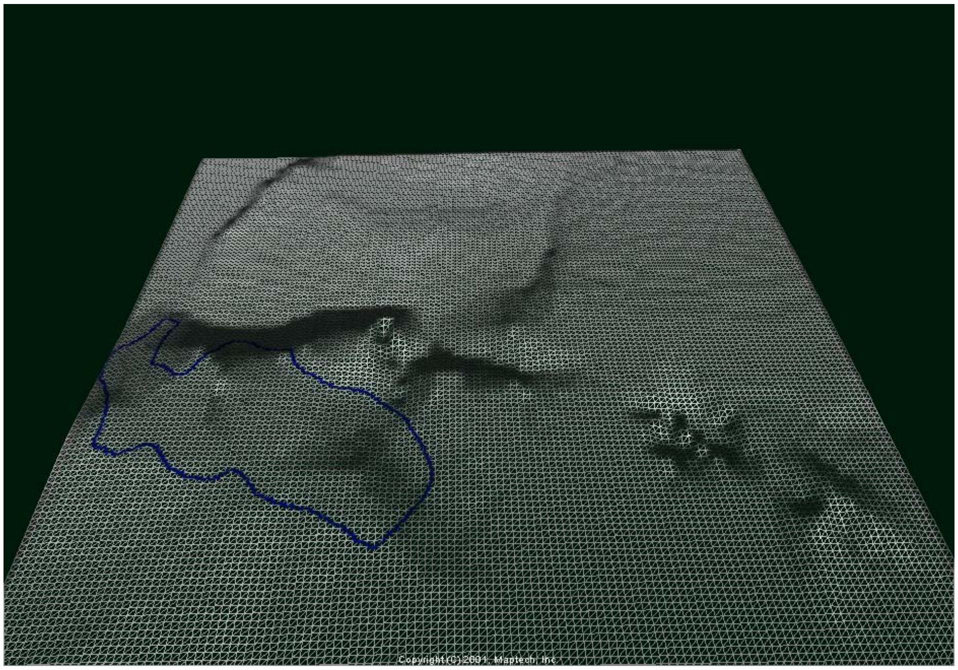

Figure B9 – East Nunatuq wire frame model.

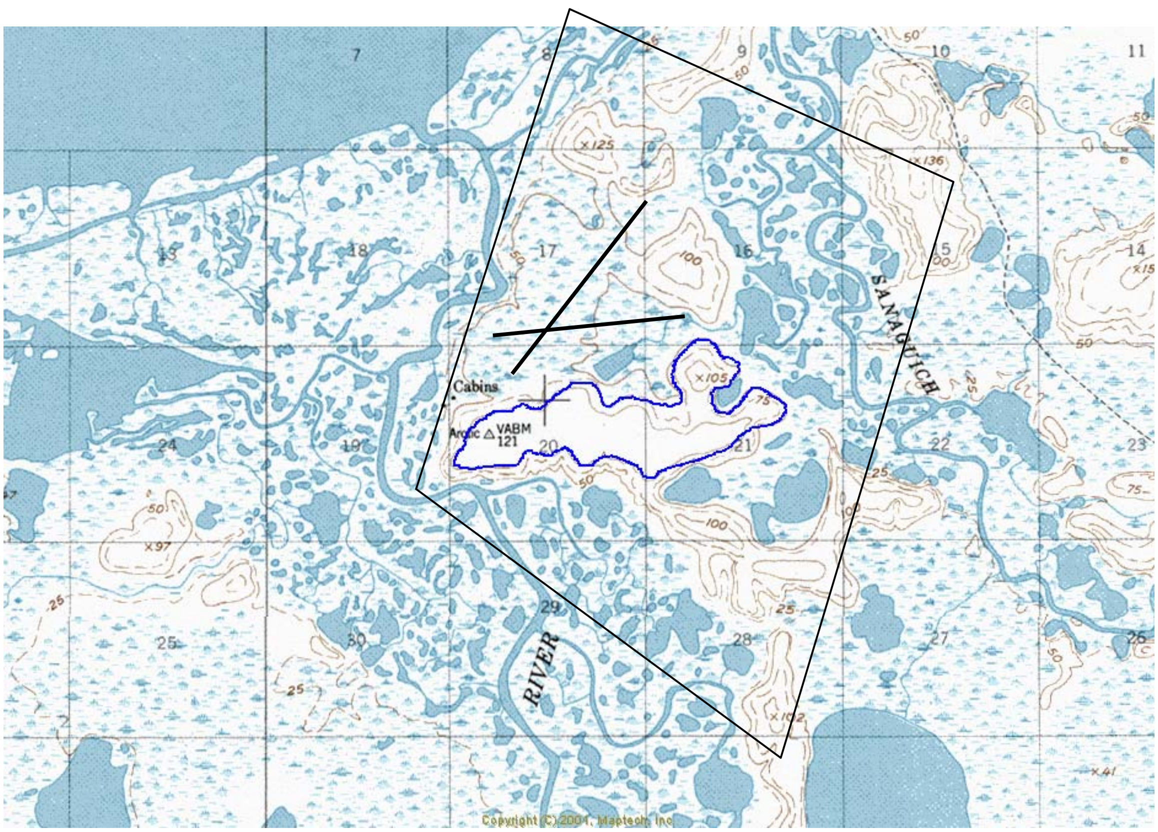

Figure B10 – Arctic location map. Blue outline is the site investigated for the village. Dark black lines are a possible airstrip alignment. Light black lines encompass the original investigation area.

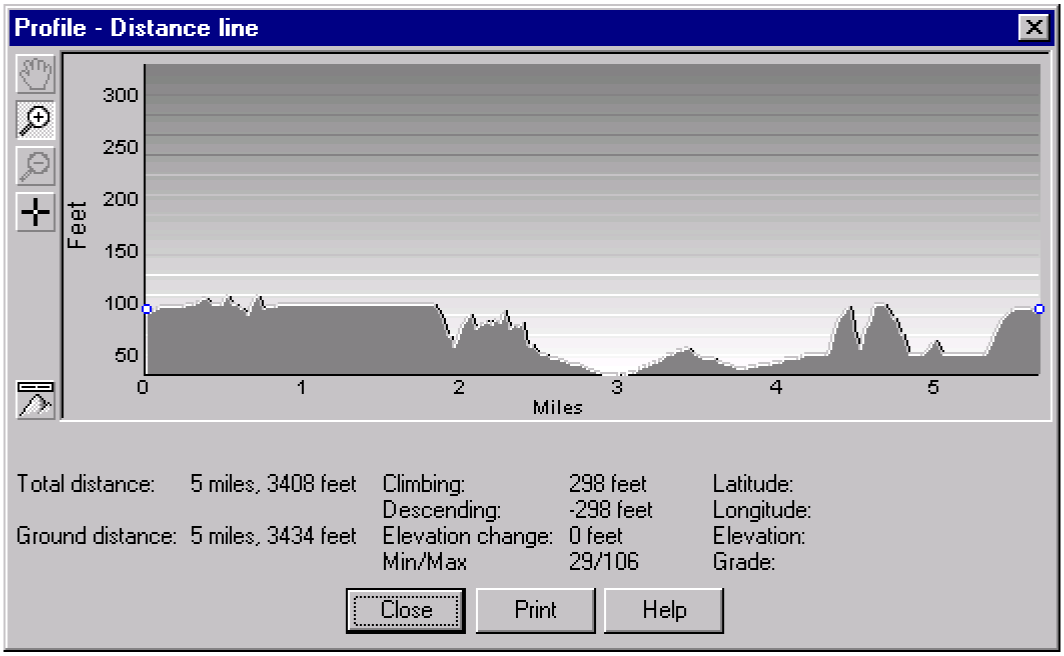

Figure B11 – Arctic perimeter profile

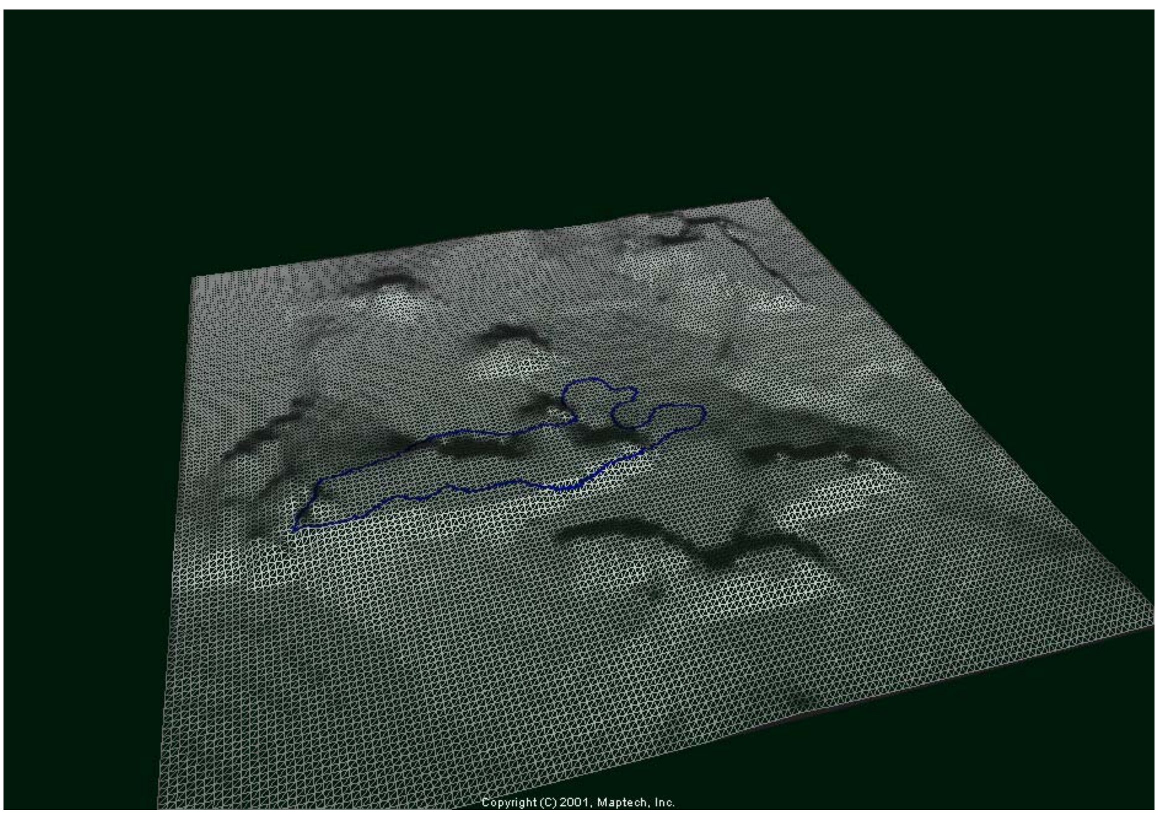

Figure B12 – Arctic wire frame model

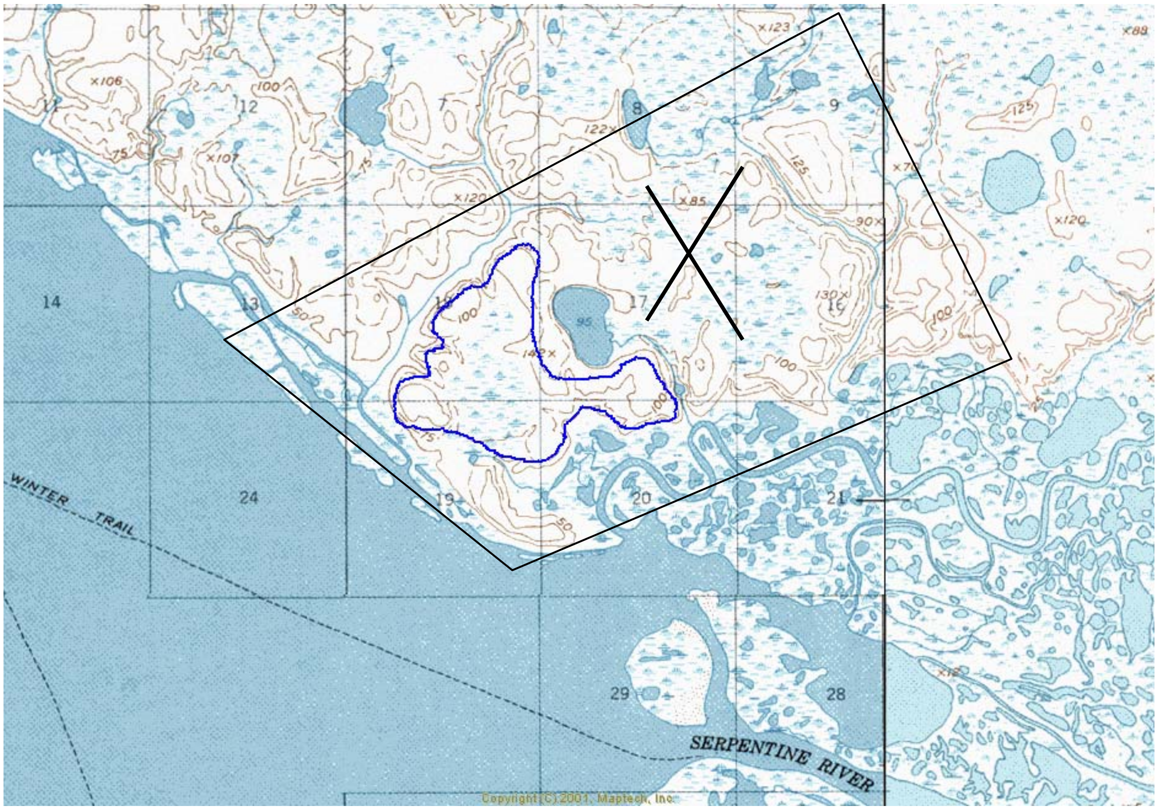

Figure B13 – Igloot location map. Blue outline is the site investigated for the village. Dark black lines are a possible airstrip alignment. Light black lines encompass the original investigation area.

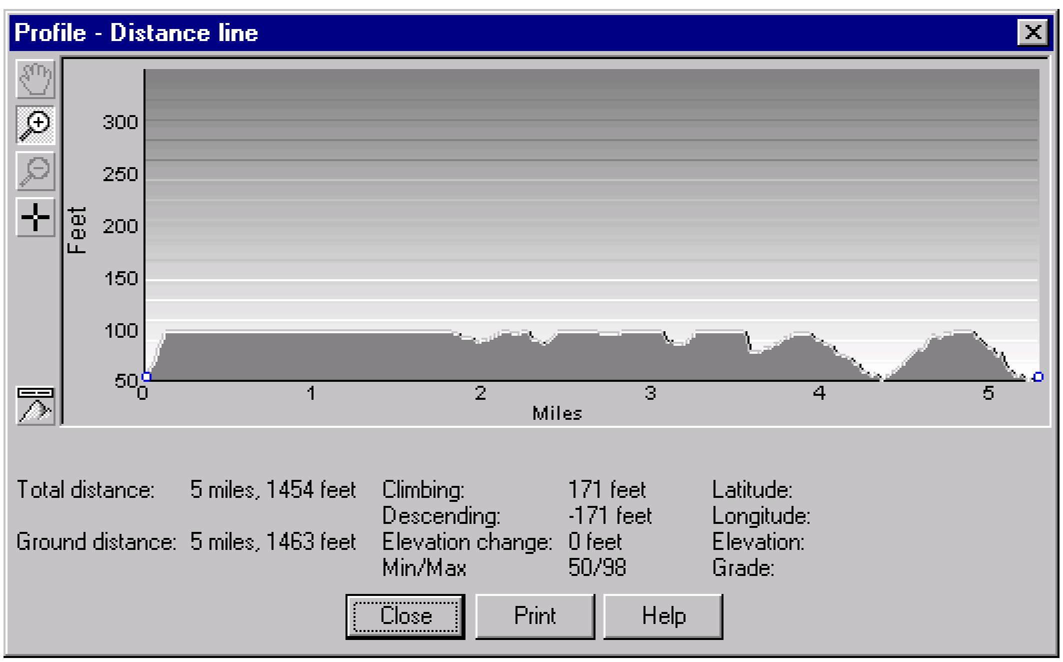

Figure B14 – Igloot perimeter profile.

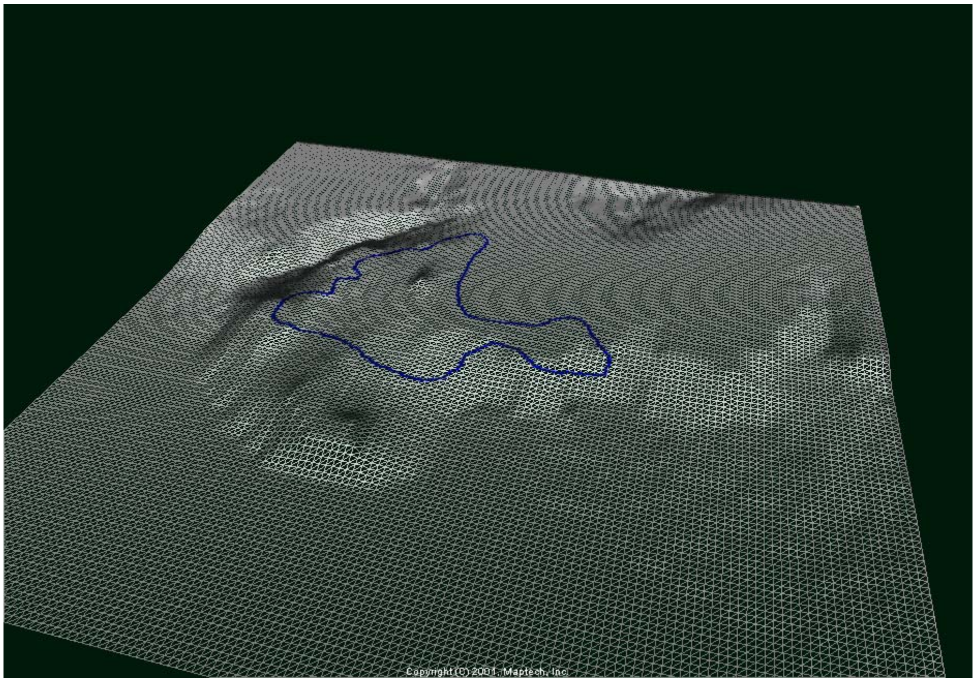

Figure B15 – Igloo wire frame model

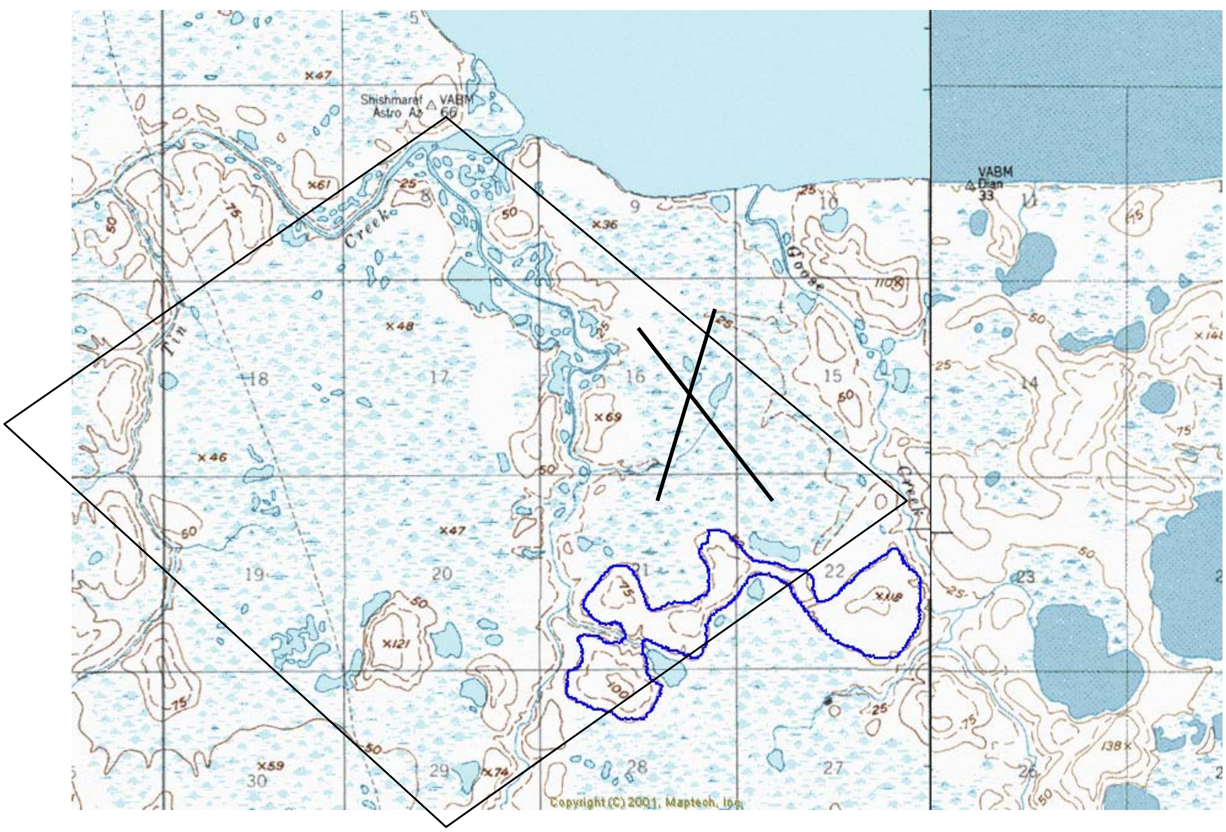

Figure B16 – Tin Creek location map. Blue outline is the site investigated for the village. Dark black lines are a possible airstrip alignment. Light black lines encompass the original investigation area.

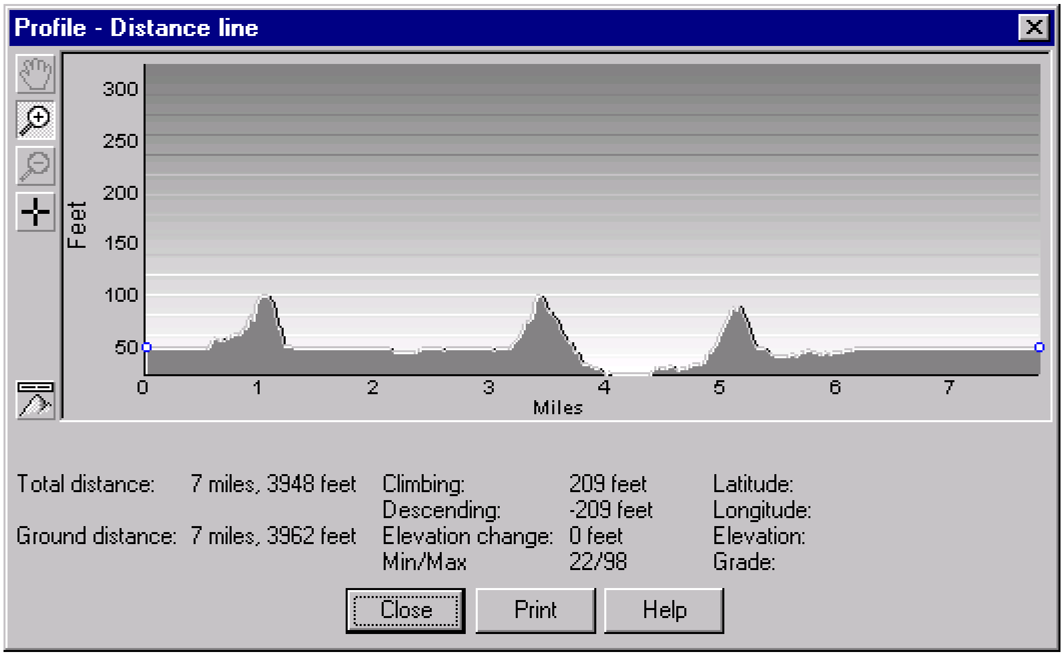

Figure B17 – Tin Creek perimeter profile.

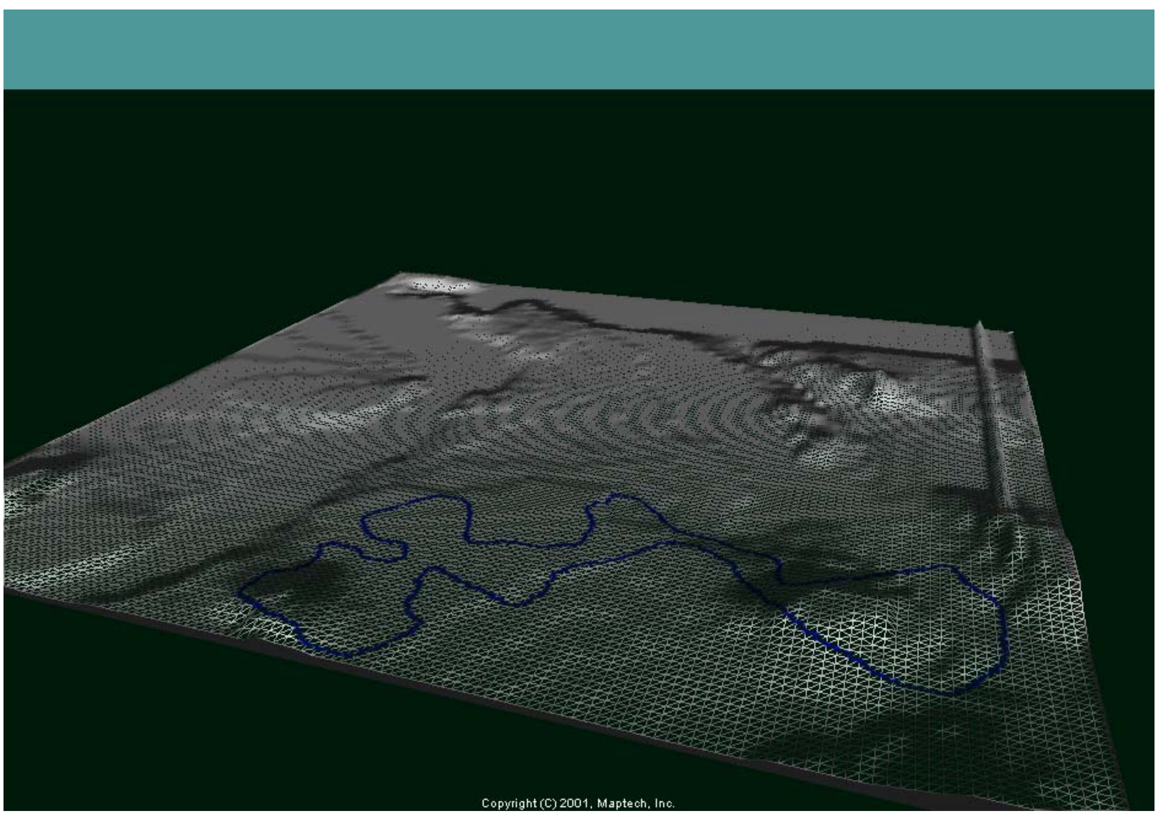

Figure B18 – Tin Creek wire frame model.

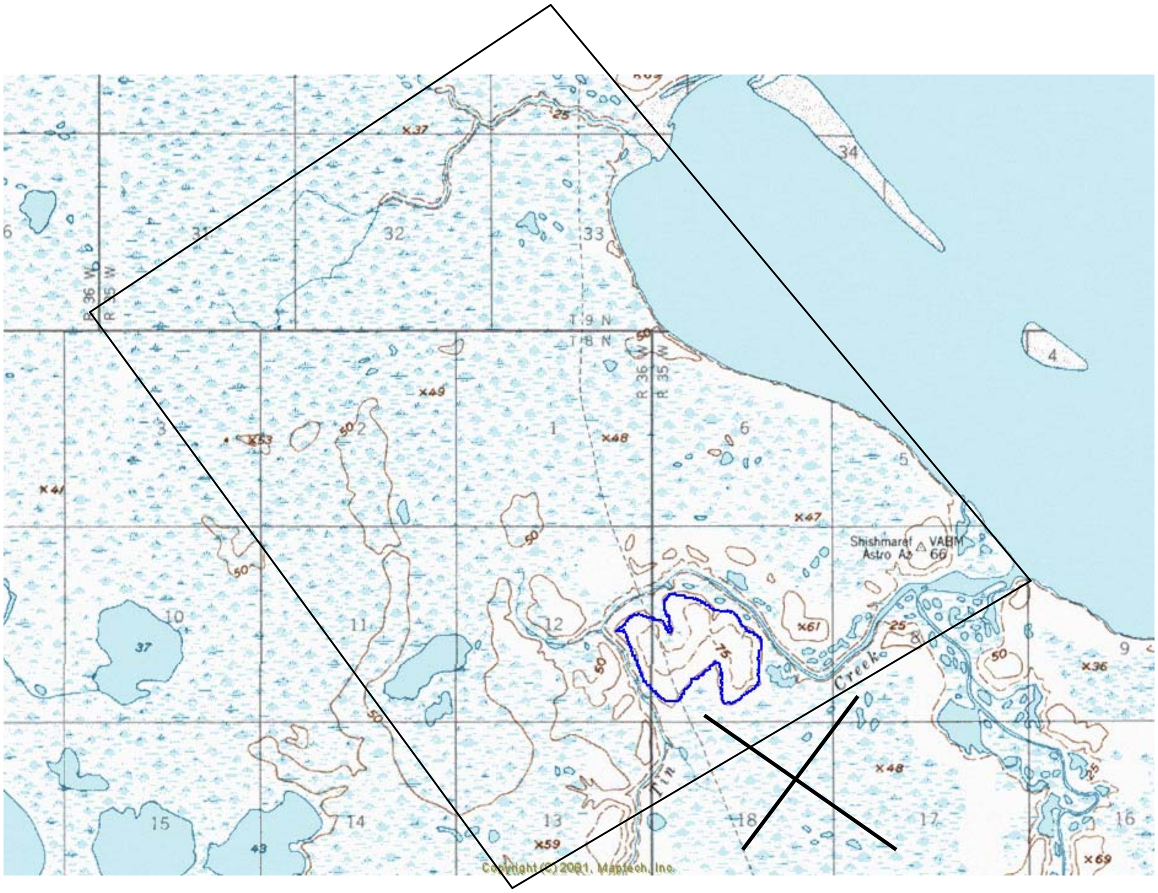

Figure B19 – West Tin Creek Hills location map. Blue outline is the site investigated for the village. Dark black lines are a possible airstrip alignment. Light black lines encompass the original investigation area.

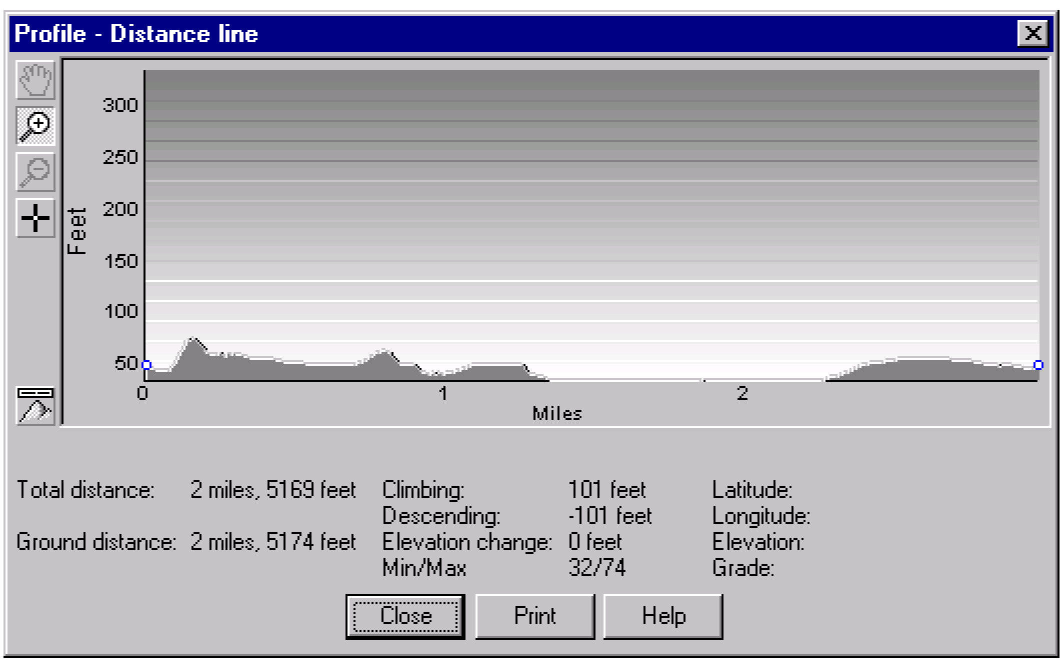

Figure B20 – West Tin Creek Hills perimeter profile.

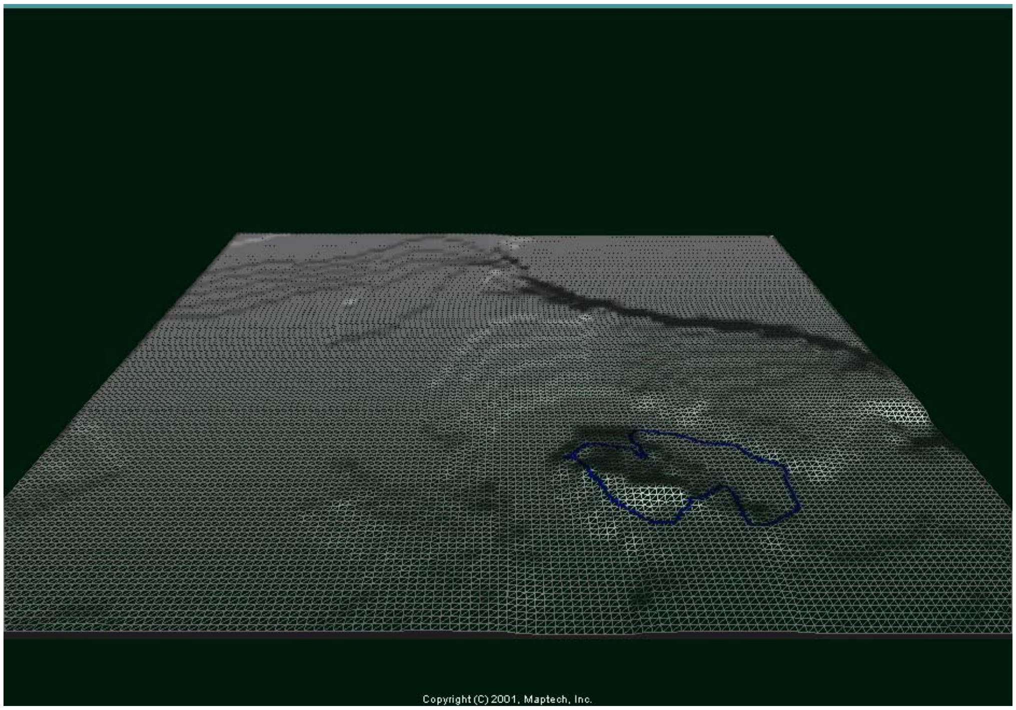

Figure B21 – West Tin Creek Hills wire frame.

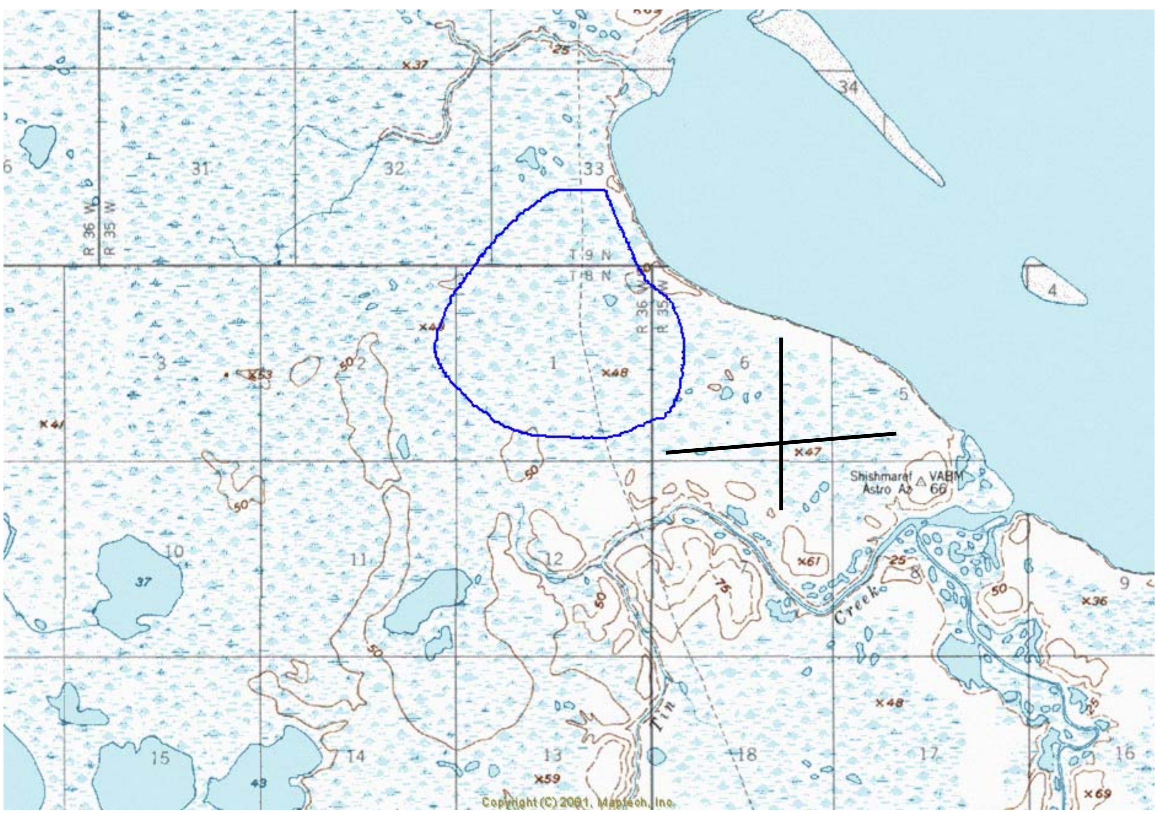

Figure B22 – West Tin Creek Flats location map. Blue outline is the site investigated for the village. Dark black lines are a possible airstrip alignment.

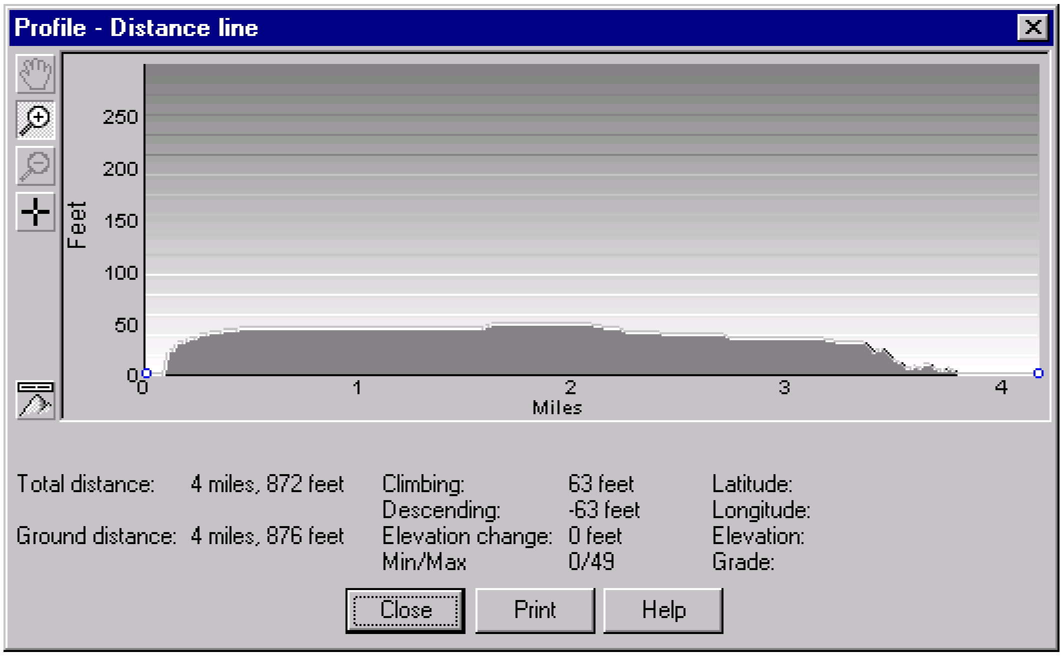

Figure B23 – West Tin Creek Flats perimeter profile.

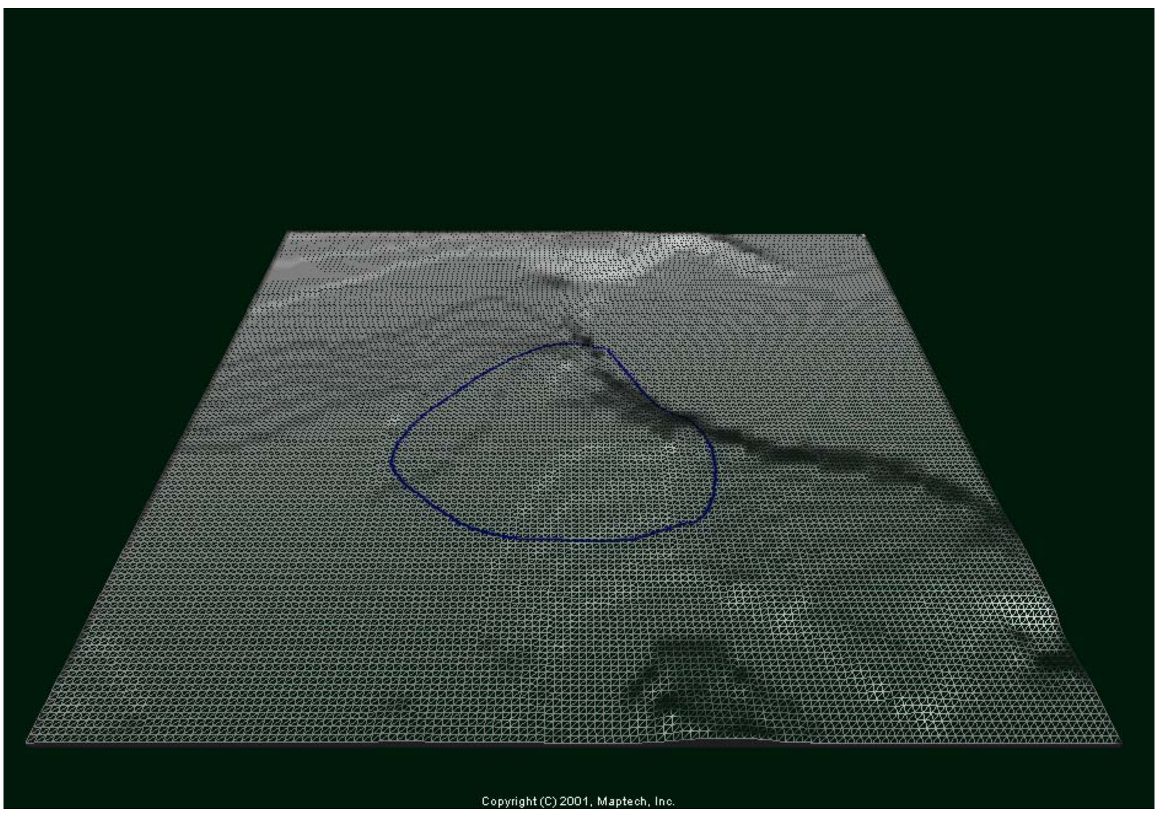

Figure B24 – West Tin Creek Flats wire frame model.