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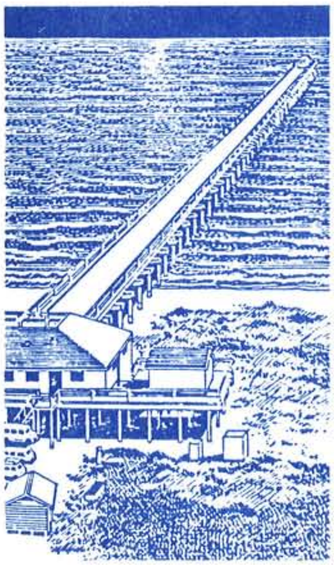

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ENGINEERING ANALYSIS OF BEACH EROSION AT HOMER SPIT, ALASKA

by

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The Coastal Engineering Research Center of the US Army Engineer Waterways Experiment Station was requested by the US Army Engineer District, Alaska, in May 1984 to provide technical assistance in identifying the cause of coastal erosion along the Homer Spit on lower Cook Inlet, Alaska, and to recommend potential long-term means of erosion control. The limited wind and wave data available for the region were subsequently collected and statistically analyzed. Deepwater wave forecasts were performed based on the wind

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statistics. A finite difference numerical model of the nearshore areas of the Homer spit and adjacent beaches at low tide was applied to predict refraction, diffraction and shoaling of the forecast deepwater waves. The model was also applied to predict breaker characteristics, expected longshore energy flux, and sediment transport rates at low tide.

Beach sample size gradation data along and across the Spit shoreline were statistically analyzed, revealing trends which point toward the probable geological evolution of the Spit. Results from the sediment analysis also allowed the numerical model to predict net expected annual longshore sediment transport rates along 11 miles of shoreline. This analysis revealed that natural hydrographic features near the base of the Spit may cause a net reversal of longshore sediment transport capacity just northward of the erosion problems along the Spit's Cook Inlet shoreline. The net transport energy toward the tip of the Spit apparently again rises where erosion is occurring. These results suggest sediment starvation is occurring in the trouble area, with consequent scour of the bottom and recession of the beach profile. Analysis of survey data along the Spit tends to confirm this hypothesis. Tidal currents near the trouble area do not appear to be a significant factor.

Three alternate erosion control measures conceived to combat this trend included two variations of a protective beach fill and a major extension of the rubble revetment existing near the base of the Spit. The extension of the revetment would allow some loss of beach material on the low tide terrace but would protect the roadway from erosion caused by wave overtopping. The beachfill plans would be more effective in preventing offshore losses and beach profile recession as well as protecting the roadway.

PREFACE

Authority for the Coastal Engineering Research Center (CERC) of the US Army Engineer Waterways Experiment Station (WES) to conduct this study was granted by the US Army Engineer District, Alaska (NPA), in the form of an Intra-Army Order for Reimbursable Services, No. EB86840032, dated 10 May 1984, and subsequent correspondence which extended the 10 May 1984 scope of work.

The study was conducted by an interdisciplinary team of engineers, scientists, and technicians of CERC in conjunction with cooperative efforts by NPA professionals. The key members of the CERC team who also authored this report are as follows: Orson P. Smith (Principal Investigator), Research Hydraulic Engineer, Coastal Design Branch; Mmes. Jane M. Smith and Mary A. Cialone, Hydraulic Engineers, Coastal Oceanography Branch; Ms. Joan Pope, Research Physical Scientist, and Dr. Todd L. Walton, Jr., Research Hydraulic Engineer, Coastal Structures and Evaluation Branch, CERC. Special recognition is due the following individuals whose supporting efforts are gratefully acknowledged: Mr. Terrence Miloser, Equipment Specialist (Electronics), Mr. Thomas Flor, Physical Scientist, Prototype Measurement and Analysis Branch, and Mr. Doyle Jones, Computer Scientist, Coastal Design Branch. Technical editing by Ms. Shirley A. J. Hanshaw and drafting support by the staff of the Publication and Graphic Arts Division, WES, are also appreciated.

The cooperative efforts of the following individuals of the NPA staff whose skills were critical in accomplishing field work in Alaska and in the subsequent data analysis are gratefully acknowledged: Messrs. Ken Eisses, Ted Bales, Henry Walters, Carl Stormer, Stanley Brust, and Dr. Paul Seguin.

The CERC efforts were directed by Dr. Robert W. Whalin, former Chief, CERC, Mr. C. Eugene Chatham, Chief, Wave Dynamics Division, and Dr. Fred E. Camfield, Chief, Coastal Design Branch. Mr. Charles C. Calhoun, Jr., is currently Acting Chief, CERC.

Commanders and Directors of WES during the conduct of the study and the preparation of this report were COL Tilford C. Creel, CE, and COL Robert C. Lee, CE. COL Allen F. Grum, USA, was Director of WES during the publication of this report. Technical Directors were Mr. Fred R. Brown and Dr. Whalin.

TABLE OF CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic yards	0.7646	cubic metres
cubic yards per year	0.7646	cubic metres per year
cubic yards per pound-year	1.6855	cubic metres per kilogram-year
Fahrenheit degrees	5/9	Celsius degrees*
feet	0.3048	metres
feet per second	0.3048	metres per second
foot-pounds per second per foot	4.448225	joules per second per metre
inches	2.54	centimetres
knots (international)	0.5144444	metres per second
miles (US statute)	1.6093	kilometres
miles (nautical)	1.8520	kilometres
miles per hour	1.6093	kilometres per hour
pounds (mass)	0.4536	kilograms
pounds per second	0.4536	kilograms per second
square feet per year	0.0929	square metres per year
yards	0.9144	metres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$.

ENGINEERING ANALYSIS OF BEACH EROSION
AT HOMER SPIT, ALASKA

MAIN REPORT

Introduction

1. Project Scope of Work: The US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center (CERC) was requested to provide technical assistance to the US Army Engineer District, Alaska (NPA), on the Homer Spit Beach Erosion Study by a sequence of three DA Form 2544 "Intra-Army Orders for Reimbursable Services" dated 8 February 1984, 10 May 1984, and 15 November 1984. The initial request was for a site visit by CERC specialists to consult with US Army Corps of Engineers (Corps), State of Alaska, and City of Homer representatives on a plan of study addressing the immediate and long-term erosion trends at Homer Spit. The site visit and consultations were accomplished in March 1984 and were followed by the May 1984 request for CERC technical assistance to investigate the coastal processes at the Spit and to recommend potential erosion control measures. The November 1984 request allowed the work to continue in fiscal year 1985. Individual tasks that were requested by NPA included:

a. Analysis of wind and wave data and a related forecast of deepwater waves.

b. Synoptic wind/wave analysis.

c. Nearshore wave transformation analysis.

d. Review of historical information.

e. Plan field data collection programs.

f. A field investigation, including:
  1. Nearshore tidal current measurements.
  2. Tide elevation measurements.
  3. Beach form inspection and material sampling.

g. Analysis of geotechnical data.

h. Preliminary sediment transport analysis.

i. Formulation and evaluation of alternative plans.

j. Preparation of a summary report.

2. Organization of the Report: This main report summarizes the descriptions of the analytical techniques applied in accomplishing the tasks outlined above and the conclusions that were drawn from the results of these analyses. The main report also summarizes the physical setting of Homer Spit and historical information related to the existing beach erosion problems. Recommendations

are made for further data collection and analysis to better define the nature of the problem and to allow more thorough design and evaluation of appropriate erosion control measures. Detailed technical descriptions of the data and analytical procedures applied in this study are presented in five appendixes: Appendix A - Wind Data Analysis and Wave Forecast; Appendix B - Wave Transformation Analysis; Appendix C - Coastal Geology; Appendix D - Sediment Transport Analysis; and Appendix E - Plan Formulation.

Existing Conditions

3. Location and Vicinity: Homer Spit is a narrow peninsula 100 to 500 yds* wide extending approximately 4-1/2 miles from northwest to southeast into Kachemak Bay, an appendage of lower Cook Inlet in southcentral Alaska (see Figure 1). The north shore of Kachemak Bay is bordered by bluffs of glacially deposited material (primarily sand and gravel with occasional clay deposits), backed by the rolling hills of the Kenai lowlands. The opposite south shore of the bay is bordered by rocky buttresses of the steep glaciated Kenai Mountains with numerous small islands and deep fjords. The head of the bay includes the mouths of the Fox and Bradley Rivers and is characterized by extensive tidal mud flats. The maritime climate of the area is characterized by winter temperatures which seldom reach below 0° F and summer temperatures seldom exceeding 70° F. Skies are usually cloudy with an annual average 28 in. of rain and 101 in. of snow. The Homer Spit and outer Kachemak Bay are not subject to sea ice, though floes of fresh water ice which may become shore fast are common in mid-winter (Gatto, 1981).

4. Regional Oceanography: Cook Inlet is approximately 200 miles long, extending from Anchorage to the Kennedy and Stevenson entrances from the Gulf of Alaska and Shelikof Strait (see Figure 1). The two entrances are defined by the southern tip of the Kenai Peninsula, the Barren Islands, and Shuyak and Afognak Islands. Shelikof Strait lies between Afognak and Kodiak Islands and the Alaska Peninsula. The inlet varies from a few miles wide near Anchorage to over 50 miles wide at its mouth. Kachemak Bay, as shown in Figure 2, is oriented east-west, extending off the lower southeast side of Cook Inlet, and has an average depth of about 25 fathoms (150 ft). Depths in the main part of Cook Inlet off Kachemak Bay are on the order of 30 to 40 fathoms (180 to 240 ft). Homer Spit, as shown in Figure 3, extends from the northern shore of Kachemak Bay near its mouth southeast, approximately 4-1/2 miles. Although open to the main body of lower Cook Inlet, Homer Spit is sheltered from any direct exposure to the Gulf of Alaska by the southern Kenai Peninsula.

5. Tides and Tidal Currents: The tides are semidiurnal but have a pronounced diurnal inequality with ranges as presented in Table 1. High Coriolis force at the 59 deg latitude and the inlet geometry cause strong cross currents and turbulence in the water column at many places during both flood and ebb tides. Tidal currents can reach 3 to 5 knots near constrictions. Clear oceanic water

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* A table of factors for converting non-SI units of measurement to SI (metric units) is presented on page 3.

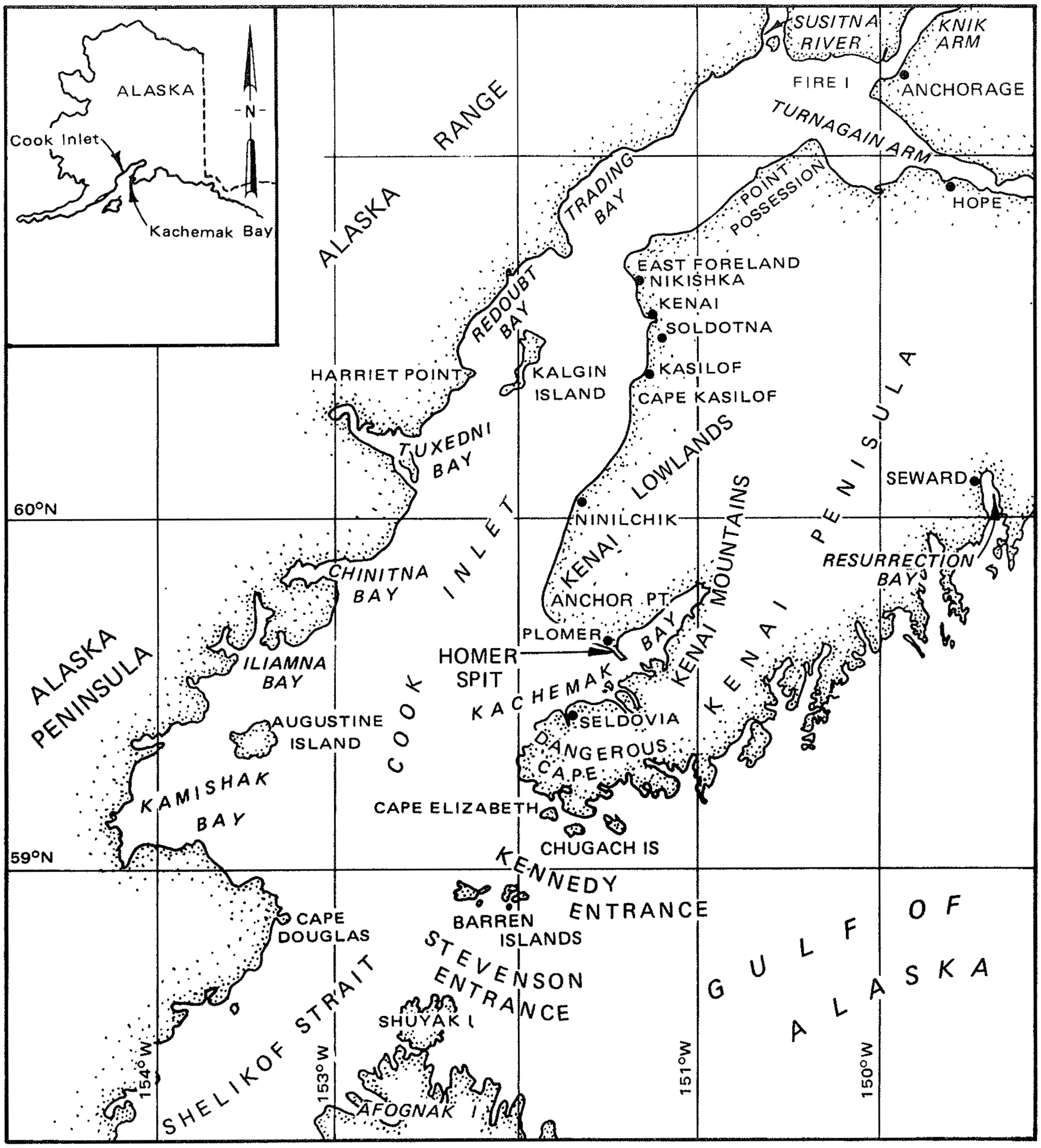

Figure 1 - Map of Cook Inlet, Alaska

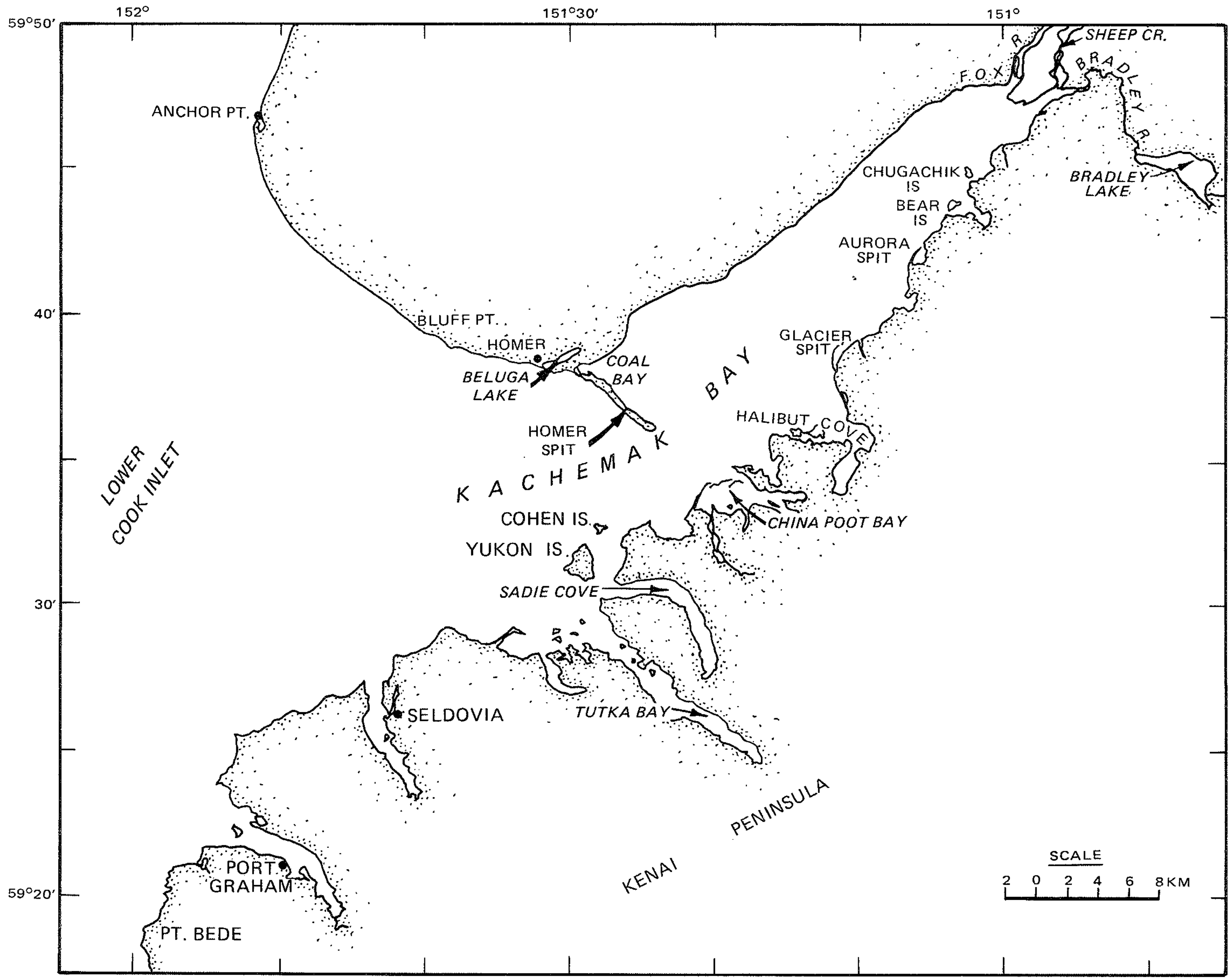

Figure 2 - Map of Kachemak Bay, Alaska

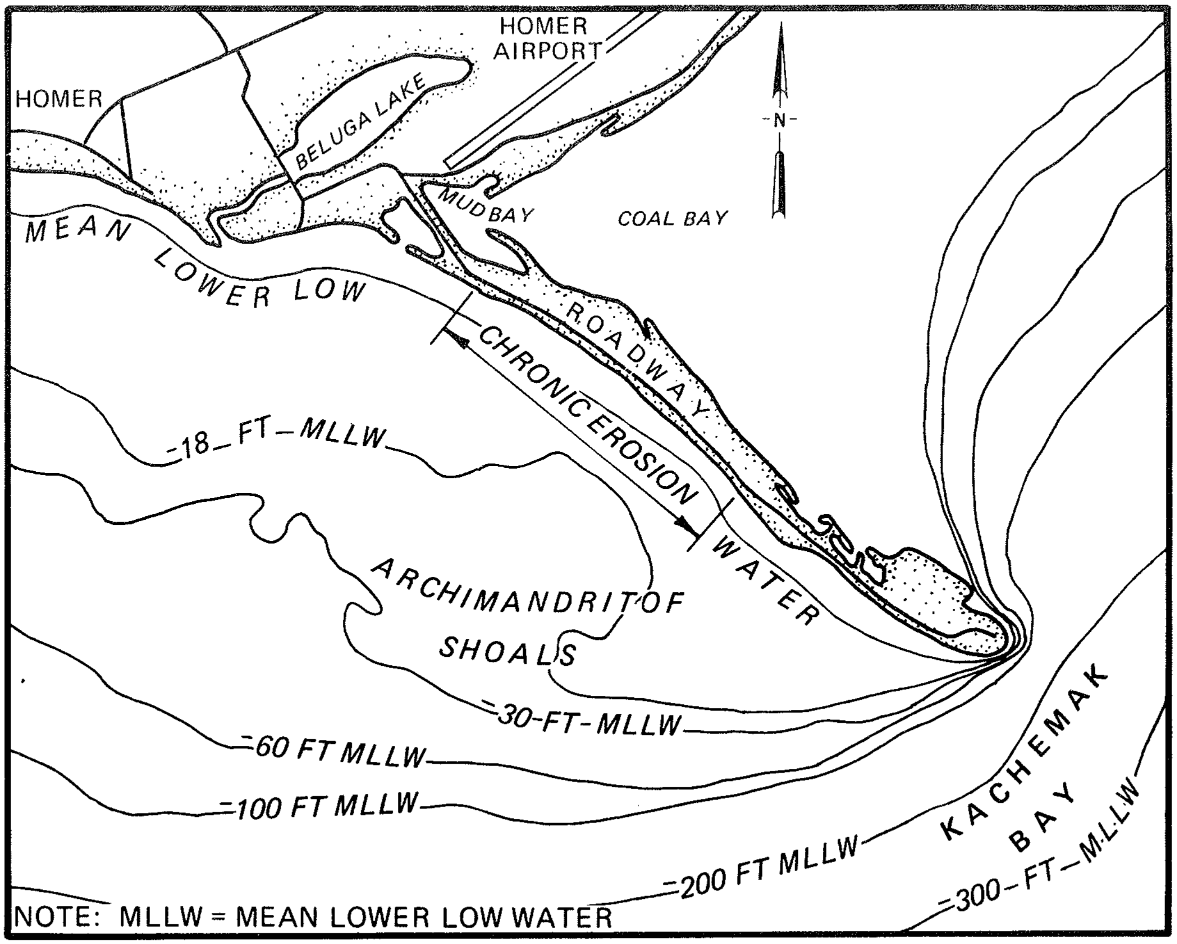

Figure 3 - Map of Homer Spit and Vicinity, Alaska

Table 1 - Tidal Ranges at Homer Spit, Alaska

Tide Level	Elevation
Estimated Extreme High Water	23.3 ft MLLW
Mean Higher High Water (MHHW)	18.1 ft MLLW
Mean High Water	17.3 ft MLLW
Mean Tide Level	9.5 ft MLLW
Mean Low Water	1.6 ft MLLW
Mean Lower Low Water (MLLW)	0.0 ft (datum)
Estimated Extreme Low Water	-5.5 ft MLLW

reaches into lower Cook Inlet well north of Kachemak Bay, thus reducing the high suspended sediment load found in upper Cook Inlet to less than 2 mg/l (Gatto, 1976).

6. Current Erosion Problems: Homer Spit has been intermittently used as a landing by vessels for 2 centuries, but the last 25 years have seen most of the now heavy development on the outer portion for recreational and commercial activities. A single 2-lane roadway, originally built in 1927, leads out to these developments following the southwestern shore of the Spit, as seen in Figure 4. This roadway was predated by a railroad built in the 1890's serving a coal exporting operation. The inshore half of the existing roadway has been a continual source of maintenance problems since its original construction. Severe storms accompanied by high water levels and wave action have overtopped and washed out stretches of the roadway causing the road to be closed and undergo major repairs on several occasions. Various means of preventing this damage have been installed over the years, including wooden beach groins (now only remnants are visible), a revetment of old car bodies (no longer visible), a wooden bulkhead (no longer in place), a rubble revetment, a section of vertical steel sheet-pile wall, and a concrete slab revetment at the toe of the sheet pile (now about 80 percent destroyed). These last three features are seen in Figure 5. Danger to motorists and potential failure of the roadway remain a substantial threat during storms that are likely to occur once or twice in any year.

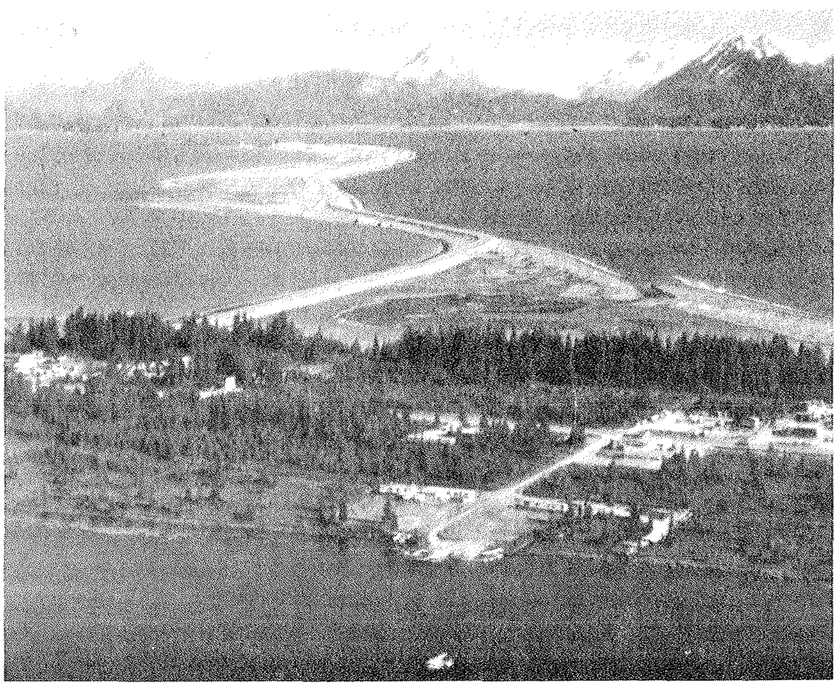

Figure 4 - August 1984 photo of Homer Spit, Alaska

Figure 5 - August 1984 photo of sheet-pile wall, failed concrete slab toe protection, and rock revetment beyond

7. The 1964 Earthquake: Southcentral Alaska experienced a major earthquake on 27 March 1964 which was responsible for extensive structural damages over the entire region, significant geological effects, and a tsunami which inundated several coastal communities. Prior investigations of the quake's apparent effects on Homer Spit revealed that differential subsidence from a total of about 3 ft at the base to nearly 7 ft at the tip occurred. This subsidence included tectonic subsidence of 2 to 3 ft and soil compaction of 1 to 4 ft. One, possibly 2, submarine landslides occurred at the tip of the Spit. The outer breakwater of the boat harbor built in 1962 on the southeastern side of the tip was almost completely destroyed by a submarine landslide, and evidence points to another landslide on the opposite side of the tip (Waller, 1966). The Kenai Peninsula at Homer also subsided 3 to 4 ft, thus submerging the toe of the bluffs which provide sediment to the Spit's southwestern littoral zone. The erosion problem along the Spit road was chronic prior to the earthquake. The subsidence caused by the earthquake initially exposed this area and the rest of the Spit shoreline to tidal currents and wave attack higher on the vertical profile, but the sediment supply to the Spit system was at the same time dramatically increased. The initial recession of the Spit shoreline averaged 10 to 15 ft, with 30 ft in places and one localized 56-ft recession. Within a month new storm berms had built themselves all along the Spit's southwestern shoreline. One year later the Spit's southwestern beach appeared to have reached a new stable configuration (Stanley, 1966). The erosion problem along the rebuilt roadway reappeared to much the same degree that it

existed prior to the earthquake. Quantitative information available is not sufficient to determine to what degree the earthquake may have exacerbated the problem, but it appears the post-quake quasi-equilibrium condition that was rapidly reached is equivalent to pre-quake conditions.

8. Prior Erosion Studies: A pre-earthquake report by Stanley and Grey (1963) for the State of Alaska Department of Natural Resources documented erosion control efforts to date along the Spit road and called for a comprehensive study of erosion all along the Spit shoreline. The efforts of Waller (1966) and Stanley (1966) to document the specific effects of the 1964 earthquake on the Homer area included observations of the erosion problem along the southwestern shore. The most pertinent of these observations are mentioned above. A Kachemak Bay Beach Erosion Study by the Corps, which had been authorized in 1963, was begun in earnest in 1964 by the Alaska District in cooperation with the State of Alaska Department of Natural Resources. The first available report from this study (Gronewald and Duncan, 1965) documented in detail the efforts that had taken place on the Spit to combat the immediate effects of subsidence. It concluded that a program of consistent long-term measurements would be necessary to predict future trends in coastal processes. The final report under this authority, published by NPA (1974), concluded that no major erosion problems existed at that time due to the effectiveness of erosion control measures already in place. The most recent study of erosion trends was performed by Woodward-Clyde Consultants (1980) which included a thorough literature review and a minimal amount of survey and current measurements. This study concluded that tidal currents along the Spit were not as significant as wave-induced sediment transport and recommended a program of field measurements which would identify localized trends in more detail as an aid to coastal zone management decisions.

Wind Analysis and Wave Forecast

9. Available Data: Measured wind data were available from a Corps maintained anemometer on the tip of Homer Spit, a National Weather Service anemometer located at the Homer Airport on the mainland near the base of the Spit, and a National Data Buoy Office (NDBO) buoy located in Cook Inlet approximately 40 nautical miles southwest of Homer (see Figures 1, 2 and 3). The Spit anemometer data included measurements from 1965 to 1982 but with significant gaps of missing data and inconsistent means of reducing the recordings from analog to digital form. The airport anemometer provided measurements from 1951 to 1982, also with some data gaps. This instrument was situated in a location partially sheltered by trees and local topography. The NDBO buoy provided measurements from 1977 to 1979, but it was reported by National Oceanic and Atmospheric Administration (NOAA) investigators (Macklin, et al., 1980) to have been located in a drastically different wind regime from that of Homer Spit. A brief record of data in a partially reduced form was also available from two accelerometer wave buoys placed in outer Kachemak Bay and just off the base of the Spit by the Alaska District Corps of Engineers in 1984 (see Figures 2 and 3).

10. Wind Data Analysis: Wind measurements from all three sources were corrected to equivalent 10-m elevation velocities and adjusted for data sampling methods, overland/overwater readings, air-sea temperatures, as appropriate,

and coefficient of drag to estimate the associated wind stress factor, according to the guidance of the Shore Protection Manual (SPM) (1984). These corrections and adjustments allowed direct application of the "JONSWAP" wave forecasting relations. A frequency analysis by velocity and direction was plotted in the form of wind roses for each of the data sources, as presented in Appendix A. The winds were found to be funneled through 2 axes: one along lower Cook Inlet and Shelikof Strait (northeast-southwest) and the other from the Kennedy and Stevenson Entrances to Kamishak Gap (east-west). The NDBO buoy data tended to confirm this previous finding of Macklin, et al. (1980). Winds at Homer Spit were also observed to be heavily influenced by the thermal effects of the icefield on the opposite side of Kachemak Bay causing winds out of the bay. Winds from Cook Inlet entering Kachemak Bay are of principal concern with respect to erosion of the western shore of Homer Spit.

11. Comparison of Data: Paired data from the three sources were compared to each other with disappointing results. Statistical correlation was not significant, though visual inspection of the wind roses showed similar directional trends between the airport and Spit anemometer records. The NDBO buoy data showed no meaningful relation of any kind to either the Spit or airport data. The strong orographic influences and lack of reliable synoptic pressure data over lower Cook Inlet precluded any simulation of wind fields with atmospheric boundary layer numerical models. It was concluded that additional measurements at new locations would be necessary to reliably resolve the wind fields near Homer Spit but that both the existing airport and Spit data should be independently applied to forecast the wave climate in the interim.

12. Wave Forecast: The JONSWAP relations for deepwater wind wave growth were applied according to the guidance of the SPM (1984) with the assumption that the winds recorded at the Spit and airport anemometers also existed over the lower Cook Inlet fetches of interest. Wind stress factors were applied according to their probability of occurrence to forecast the spectrally-based deepwater wave height (H_{mo}) and peak spectral period (T) which would theoretically have been generated. The results of this analysis are presented in Tables 2, 3 and 4 for three sectors covering the exposure of the Spit's western shore. A limited amount of wave data measured off Homer Spit in 1984 was compared to waves forecast with concurrently measured wind data from the Spit anemometer. Statistical correlation and inspection of scatter plots (presented in Appendix A) indicated that the forecast waves were conservative in terms of wave height. Wave period was not found to compare well, but the measurement technique was known to be incompatible with the spectrally based period forecast by the JONSWAP relations. The overall comparison of the forecast versus measured waves was considered to be acceptable, considering the many simplifying assumptions that were necessary.

13. Wave Transformation Analysis: The estimation of wave transformation from deep water to the low water shoreline of the Spit was accomplished by application of an iterative finite difference numerical model. A rectangular grid was generated which included 72 cells in the longshore direction covering about 60,000 ft from Bluff Point on the mainland to beyond the tip of the Spit. The grid covered 22,500 ft offshore of the low water line with 76 cells, as illustrated in Appendix B . The grid was prepared with data from NOAA boat sheets from surveys conducted in 1976, which extended only to Mean Lower Low Water (MLLW). No high water hydrography was made available in time to incorporate into the grid. The numerical model predicted conditions at

Table 2 - Wave Forecast: Sector 281.25 deg - 303.75 deg

Wind Stress Factor (mph)	H_{mo} (ft)	T (sec)	Probability Distribution Spit	Probability Distribution Airport
2.5	0.5	2.7	2.83	1.33
7.5	1.5	3.9	2.63	1.29
12.5	2.6	4.7	1.77	0.52
17.5	3.6	5.2	1.06	0.20
22.5	4.6	5.7	0.53	0.07
27.5	5.7	6.1	0.27	0.01
32.5	6.7	6.4	0.11	0.005
37.5	7.7	6.7	0.04	0.0004
42.5	8.7	7.0	0.01	-
47.5	9.8	7.3	0.006	-
52.5	10.8	7.5	0.003	-

Table 3 - Wave Forecast: Sector 258.75 deg - 281.25 deg

Wind Stress Factor (mph)	H_{mo} (ft)	T (sec)	Probability-Distribution Spit	Probability-Distribution Airport
2.5	0.6	3.0	4.96	3.75
7.5	1.8	4.3	4.79	3.61
12.5	3.0	5.1	3.86	2.28
17.5	4.1	5.7	2.46	1.27
22.5	5.3	6.2	1.44	0.61
27.5	6.5	6.7	0.67	0.21
32.5	7.7	7.1	0.32	0.06
37.5	8.9	7.4	0.16	0.01
42.5	10.1	7.7	0.07	-
47.5	11.3	8.0	0.04	-
52.5	12.4	8.3	0.02	-
57.5	13.6	8.5	0.006	-

Table 4 - Wave Forecast: Sector 236.25 deg - 258.25 deg

Wind Stress Factor (mph)	H_{mo} (ft)	T (sec)	Probability Distribution Spit	Probability Distribution Airport
2.5	0.7	3.2	8.49	7.72
7.5	2.0	4.7	8.30	7.76
12.5	3.3	5.5	7.18	6.30
17.5	4.6	6.2	5.29	4.27
22.5	6.0	6.7	3.34	2.15
27.5	7.3	7.2	1.97	0.74
32.5	8.6	7.6	1.28	0.21
37.5	10.0	8.0	0.79	0.04
42.5	11.3	8.3	0.39	0.01
47.5	12.6	8.6	0.17	0.002
52.5	13.9	8.9	0.05	-
57.5	15.3	9.2	0.018	-
62.5	16.6	9.5	0.009	-
67.5	17.9	9.7	0.006	-

each grid cell after the effects of refraction and diffraction for a specified deepwater condition at the grid boundary with the following assumptions:

a. Bottom slopes were small.

b. Waves were linear, monochromatic, and irrotational.

c. Wave reflection was negligible.

d. Energy losses due to bottom friction or other factors acting outside the surf zone were negligible.

14. Wave conditions just prior to breaking were simulated according to the criterion of the SPM (1984) by transforming wave heights to 78 percent of the depth, with application of Snell's Law of refraction and the assumption of straight parallel contours within each grid cell. Longshore energy flux (Pls) was computed from the estimated breaking conditions at each of the 72 longshore grid cells. Wave transformation of an ensemble of deepwater conditions, based on the results of the deepwater wave forecast for both the Spit and airport data, was simulated. The expected longshore energy flux for each grid cell was estimated by adding all the energy flux values estimated, each weighted by its associated probability of occurrence in the period of record. The results of this analysis are presented graphically in Appendix B.

Analysis of Geotechnical Data

15. Data Available: The geotechnical data available for review and analysis consisted of regional and site-specific information published in a number of journal articles and of sediment size distribution data provided by NPA from

beach samples taken at the Spit in August 1984. The location of these samples is shown in Figure 6, along with the location of concurrently surveyed beach profiles.

16. Geological History: Published information on the geology of southcentral Alaska indicates that the region surrounding Homer Spit has experienced at least five Pleistocene ice advances, separated by comparatively short periods of soil formation and weathering. The closest radiocarbon dates revealing disappearance of glaciation were at Ninilchik, 40 miles north of Homer, which identified a 9,000 to 10,000-year-old deposit of basal peat. Borings taken near the tip of Homer Spit contain shells, sand and gravel, suggesting that the tip is littorally derived. No subsurface information was available at the base of the Spit. Consequently, there is little basis on which to speculate whether the Spit is entirely derived or whether it rests on a relict glacial morraine. Given the known glacial and post-glacial history of the local area, it is probable that the entire Spit is younger than 7,000 to 8,000 years. A single sample from August 1984 taken about 5 ft below the surface of an ancient beach ridge at the middle of the Spit was radiocarbon dated as organic material deposited approximately 800 years ago. This evidence is not conclusive but points toward the possibility that the entire Spit was formed by littoral processes.

17. Sediment Sample Analysis: The beach material samples taken in August 1984 were subjected to standard size gradation tests whose results are presented in Appendix C. This gradation data was also subjected to a statistical cluster analysis which identified dissimilar subgroups or "clusters" of sample types according to their varying distributions of specified material size classes. Five clusters were defined: (1) dominated by medium sand, (2) widely graded, dominated by gravel and cobbles; (3) widely graded, dominated by medium sand and gravel; (4) dominated by fine sand; and (5) dominated by silt. These clusters were found to have been located at predictable points along the Spit and across the beach profiles. The coarser clusters defined the upper beach, except at the tip, where no low tide terrace of finer materials existed and coarse material continued beyond low tide. The medium to fine sand clusters defined the low tide terrace existing along most of the Spit's western shore. The 5th subgroup had only 2 observations. The results of the cluster analysis seemed to follow the energy regime of the Spit's western beach profiles quite well. A future use of this information would be to identify the exact source of the sediment supply, though it is fairly certain that it is the bluffs from Homer northward to Anchor Point. Also it would be useful in evaluating the effectiveness and potential biological suitability of beach fill material.

18. Hypothesis of Morphological Regimes: The sum of results from the analysis of geotechnical data available, review of previous findings of others and inspection of aerial photos taken before the 1964 earthquake, and the extensive construction activities that followed lead CERC specialists to form the hypothesis summarized below and discussed in more detail in Appendix C. The outer portion of the Spit shows ancient beach ridges in older aerial photos which are recurved toward the head of the Bay indicating long-term accretion with consistent strong wave energy toward the tip. The coarse cluster groups typical of this region support the indication of consistently high wave energy. Older photos of the central body of the Spit show long relatively straight beach ridges slightly concave toward Cook Inlet, indicating a

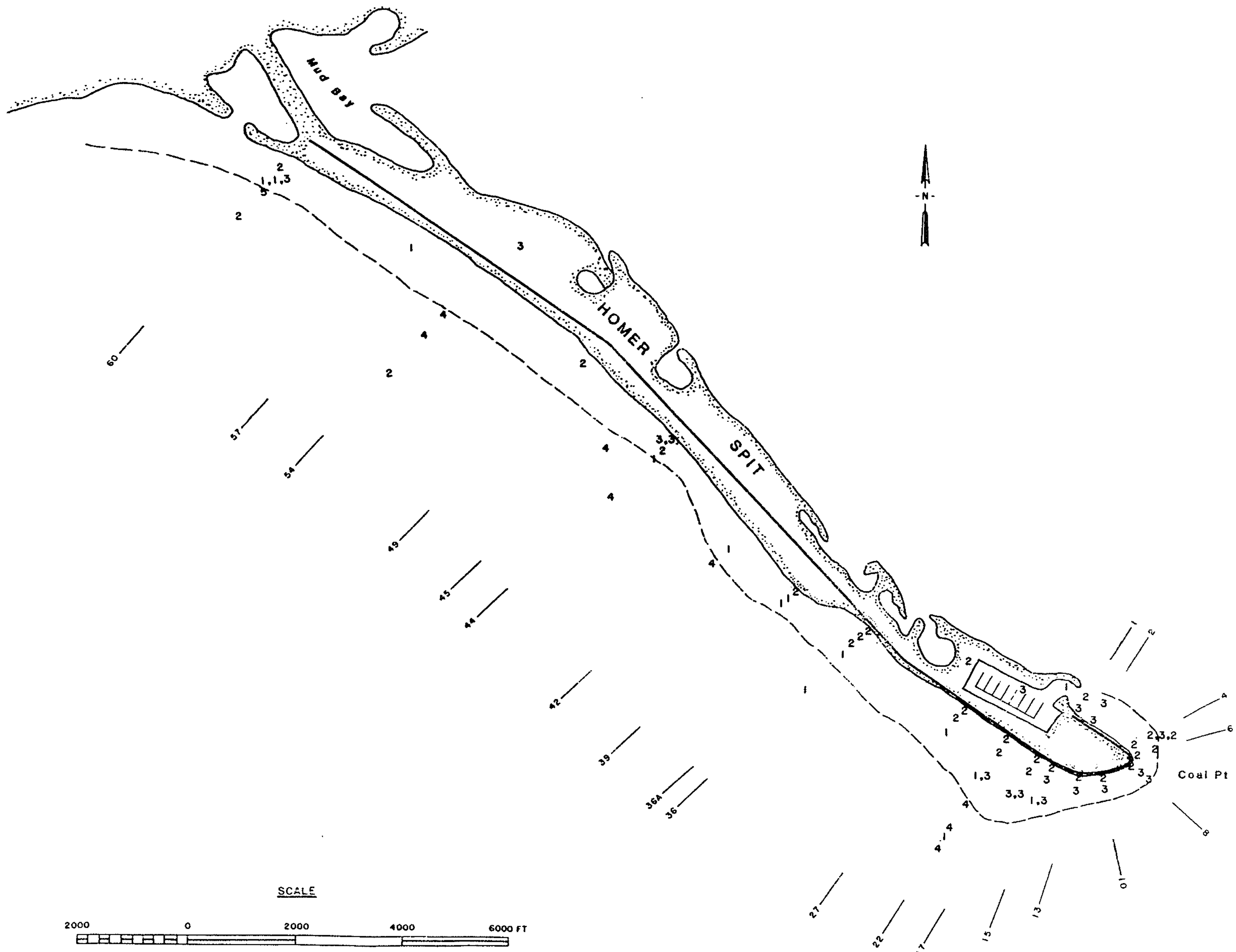

Figure 6 - Beach profiling plan and sample locations for August 1984 survey of Homer Spit, Alaska

long-term divergence of wave energy. This hypothesis has been demonstrated to be the present condition by the wave transformation analysis of this study. Concave divergent zones are typically eroding, as is the case at the northern end of this regime in the vicinity of the sheet-pile wall.

19. The base of the Spit again shows recurved beach ridges that have responded to wave exposure consistently (over the long term) toward the tip. The low tide terrace is currently broad, however, which provides significant protection to the upper beach. The roadway has also been artificially protected in this area since its construction. These 3 regimes seem to indicate initial formation of the Spit in a classical manner, possibly followed by a long period of mild conditions (perhaps with lower water levels) when sediment loads were high (possibly due to unusual stream discharges). The end of this epoch returned the Spit to more severe wave exposure and a more modest sediment supply. The wave energy divergence along the midsection now prevents continuous flow of sediments from the base to the tip, and the erosion of this section has begun to partially fulfill the sediment demands toward the tip. A decrease of sediment supply to the tip by extensive hardening of the midsection could bring about erosion at the tip.

Sediment Transport Analysis

20. Available Data: The estimation of sediment transport rates along Homer Spit was accomplished by review and analysis of the following information:

a. Aerial photography at various scales provided by NPA.

b. A single set of 67 beach profiles taken in August 1984 from the approximate centerline of the Spit offshore to well beyond the active nearshore zones, from the tip of the Spit to its base along the western side. These survey data were provided by the State of Alaska in numerical form only. Interpretation of the associated contour shapes was not possible within the project schedule. The location of these profiles is illustrated in Figure 6.

c. Sediment classification and size gradation data provided by NPA for samples taken in August 1984 and subsequent analysis of this data performed at CERC as discussed above and Appendix C.

d. The CERC wave transformation analysis discussed above.

e. Current measurements taken off the tip of the Spit and at intervals off its western shoreline in August 1984. These measurements were taken primarily as calibration and verification data for a tidal circulation numerical model of Kachemak Bay which was later deleted from the scope of work for the project. Some significant conclusions were nevertheless possible from inspection of the actual measurements. Currents at three depths off the tip of the Spit were highly directional along the axis of Kachemak Bay with velocities regularly exceeding 2 knots during the 3-day period of record. Currents taken hourly over two tidal cycles along the western shore at six locations exceeded 0.5 knots in only a few instances, indicating tidal current is probably not near as significant a factor as wave induced current for sediment transport in this area. Directions along the western shore were highly erratic and difficult to measure with confidence, in part because of the low velocities.

21. Equilibrium Profile Analysis: The August 1984 beach profiles were plotted at various scales designed to reveal onshore/offshore features for comparisons between individual profiles along the Spit. The profile data below MLLW was also plotted superimposed on a curve of the form $y = -Ax^{2/3}$, which has been found by a number of specialists to indicate a condition of onshore-offshore equilibrium in many areas of the world (Bruun, 1954). More recently, the "A" coefficient has been documented as a function of the sediment grain size by Moore (1982). The mean grain size along the lower portions of the Spit shoreline is about 0.3mm, indicating an "A" value of 0.07 to 0.10. Figures 7 and 8 indicate the range of fits with these coefficients that were encountered with the Spit profile data. Figure 7 shows that the actual profiles near the tip of the Spit are considerably steeper than the theoretical equilibrium profiles, while Figure 8 shows that the actual profiles near the base (Profiles 34 through 60) appear near equilibrium. This presumably indicates that as sand is transported toward the end of the spit it is subject to much higher energy from waves and tidal currents and is lost offshore to the deep water off the end of the Spit or to the Archimandritof Shoals just off the west side of the tip (see Figure 3). The results of the wave transformation analysis and the current measurements taken in August 1984 tend to support this hypothesis. Since the tip of the Spit is not drastically retreating or growing and has been apparently stable for many years, as revealed by aerial photos, this feature is probably in a state of high energy equilibrium where the sediment supply equals the rate of loss. The profiles near the base of the Spit and in the vicinity of the roadway maintenance problems seem not to be suffering from excessive offshore losses; therefore, the erosion in this area must be caused primarily by excessive longshore transport capacity.

22. Estimation of Sediment Transport Trends: The expected longshore energy flux estimates of the wave transformation analysis were applied to Equation 4-49 in the SPM (1984) to estimate sediment transport rates. An average "K" coefficient was estimated by assuming that sediment transport conditions were divided equally between high water and low water. A "K" value appropriate for the 0.3mm sand on the low tide terrace was weighted by 50 percent and added to a zero value for the naturally armored high tide condition, yielding transport rates in cubic yards per year at each grid cell of $Q = 5{,}000 P_{ls}$. The results of these expected or long-term average transport rate estimates are illustrated in Figure 9. The problem area of the Spit, with regard to potential damage to the roadway, extends approximately from grid cells 43 to 50 (or Beach Profiles 58 to 44). Figure 9 indicates a minor reversal, or null point, at grid cell 43, presumably caused by the refraction effects of the Beluga Lake delta feature. A divergence of wave energy at this point causes a reduction in the sand supply to the shoreline at grid cell 44 and beyond where sediment transport capacity again picks up toward the tip of the Spit. This long-term starvation is the apparent primary cause of the "dog leg" shape of the Spit at this point (see Figure 4) and the associated retreat of the beach profiles which threaten the roadway. An important aspect of such a trend is that as more sand accumulates updrift of the trouble area and the profiles steepen in the starved region, the divergence of wave energy will

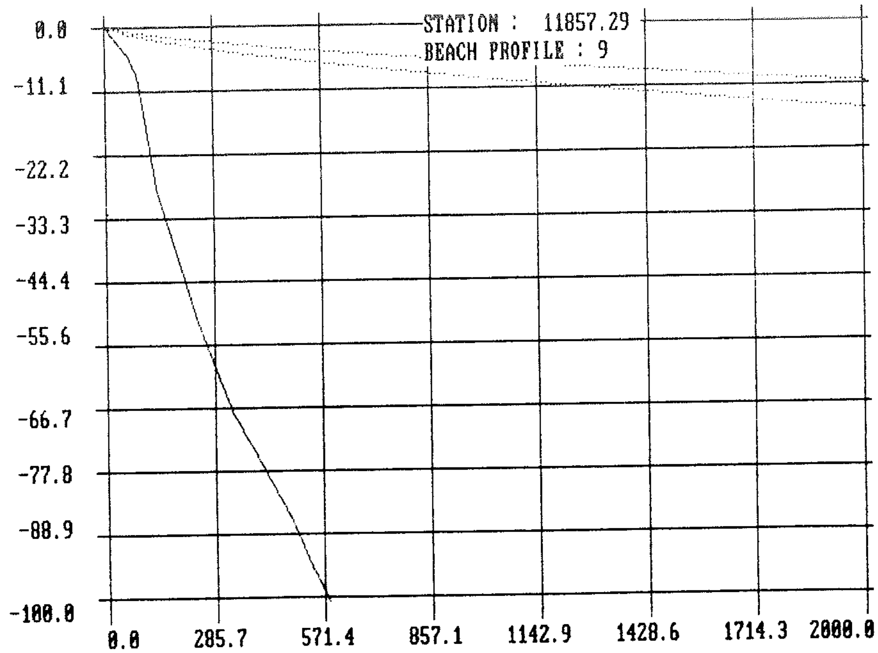

Figure 7 - Plot of actual profile (August 1984) near the tip versus theoretical equilibrium profiles (dotted lines)

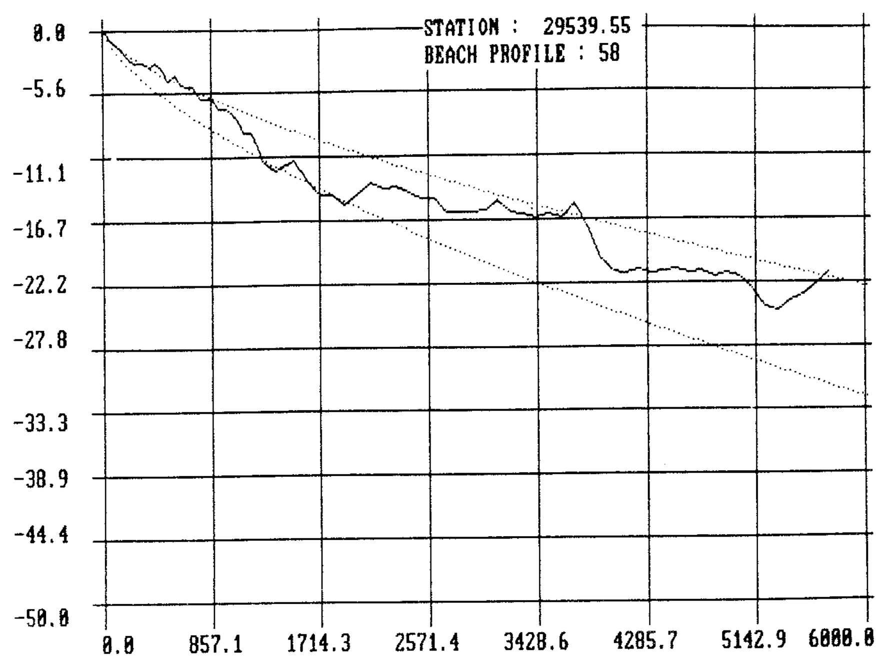

Figure 8 - Plot of actual profile (August 1984) near the base versus theoretical equilibrium profiles (dotted lines)

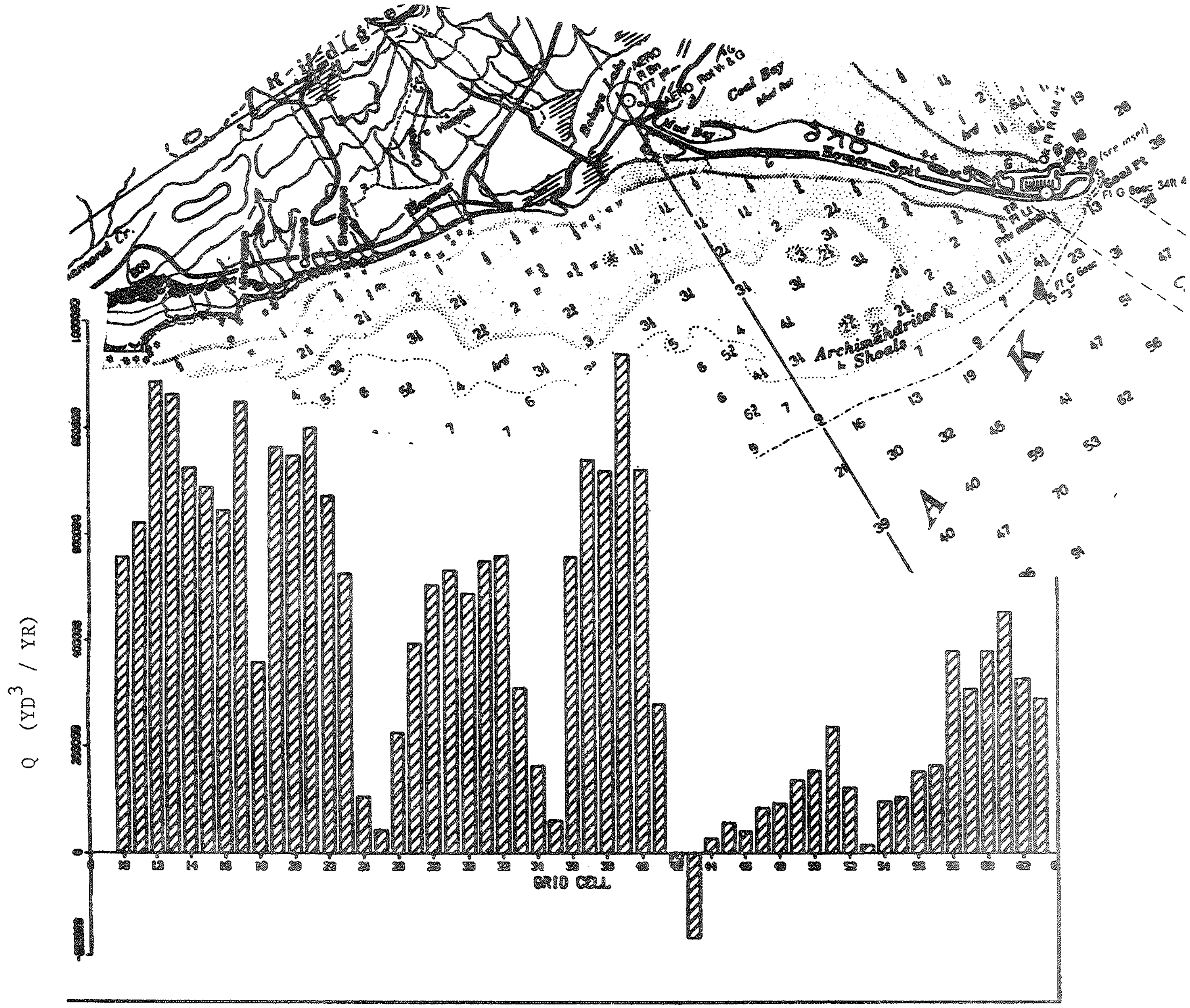

Figure 9 - Expected annual sediment transport for each grid cell (spit wind distribution)

become greater. The situation is, in other words, probably accelerating towards more complete starvation and increased erosion rates.

Formulation of Alternative Erosion Control Measures

23. The Nature of the Problem: The danger to the roadway near the base of the Spit appears to be due principally to an imbalance at that point between longshore transport capacity and longshore sediment supply. Wave reflection effects off the section of exposed sheet pile have caused local scour, but this is overshadowed by the much more extensive problem of longshore starvation. The probable accelerating nature of the wave energy divergence which is causing the cutoff of sediment supply is an important factor with which to evaluate potential erosion control measures.

24. Concepts Considered: A list of alternative coastal erosion control concepts which have proven successful in some circumstances was originally considered, including:

a. Beach groins: These structures act as barriers to longshore transport, thus trapping sediment on one side. Their major disadvantage is that as a barrier they also typically starve the shoreline immediately downdrift. This is the exact effect that is causing the existing problems; therefore, groins were eliminated from further consideration.

b. Offshore breakwater: A wave barrier parallel to the shore would reduce the wave energy that is carrying sediment away from the eroding profiles. Its length and crest elevation could presumably be chosen to attenuate the incident wave energy to a specific level, though this is difficult to achieve in practice. A barrier to wave energy would emulate the natural divergence that now occurs, thus the beach just beyond its influence would almost certainly suffer from an inadequate longshore sediment supply. This adverse feature caused offshore breakwaters to be eliminated from further consideration.

c. Protective beach fill: A protective beach fill serves two functions in that it reduces wave energy by causing wave breaking further offshore than the pre-fill condition, and it provides an artificial supply of sediment in the littoral system. This concept was considered to be worth further investigation, even though it would involve a periodic beach renourishment program.

d. Scour Protection: This concept includes all the options for artificially armoring the beach profile against wave attack and associated scour. The existing rubble revetment high on the profiles north of the sheet-pile section has apparently been successful to the extent that it has protected the roadway fill, though it provides this protection only during storms with exceptionally high water levels. The section of exposed vertical sheet pile has been less successful since its near 100 percent reflection of incident waves has caused local scour and excessive overtopping (see Figure 5). Neither existing erosion control measure protects the beach within the normal tidal range or comes close to covering the apparent extent of the overall problem. Armoring protects the material immediately under the armor, but it does not prevent continued erosion of adjacent and offshore sediments. An armored beach would continue to steepen offshore of the armor toe and would not provide any sediment supply to the downdrift beach. A scour protection arrangement which dissipates wave energy by turbulence and protects a more significant portion of the total problem area was considered worth further investigation, with the understanding that successive extensions toward the tip of the Spit would ultimately be necessary.

25. Alternative 1 - Revetment Extension and Scour Blanket: An extension of the existing rubble revetment across the sheet pile 2,300 ft toward the tip was conceived as an effective means of protecting the roadway from direct wave attack. This scour protection alternative was designed to initially account for a part of the inevitable advance of steepening profiles toward the tip of the Spit. This plan also includes a 2-ft-thick blanket of graded rock extending downslope 100 ft below the toe of the revetment, as illustrated in Figure 10. This scour blanket is intended to armor the upper beach to the present top of the low tide terrace, even after the low tide terrace has eroded and wave exposure has increased. A revetment extension without the scour blanket would also be temporarily effective in protecting the road, but the inevitable retreat of the upper beach would eventually undermine the revetment. A further extension of 1,200 ft is estimated as necessary within a 50-year economic life, nominally at the 25th year. Increasing wave exposure is also estimated to require repair or replacement of 10 percent of the original armor layer at that same interval. The shoreline response to this alternative can only be subjectively addressed at the present level of environmental data analysis, but these estimates are considered to be conservative. Specifications for Alternative 1 are:

Revetment Extension - BP 49A - 44 (2,300 ft, initially)
- crest elevation: 33 ft MLLW
- crest width: 6 ft
- toe elevation: 18 ft MLLW
- seaward slope: 1:2.0
- shoreward slope: 1:1.5 (BP 44 - 46, see Figure 11)
- primary armor: graded quarrystone (W50 = 1,200 lb) 12,500 cy
- underlayer: graded rock (W50 = 70-135 lb) 16,200 cy

Scour Blanket - BP 56 - 44 (5,600 ft, initially)
- from the toe of the revetment at 18 ft MLLW for 100 ft down the natural slope, 2 ft thick
- graded rock (W50 = 70-135 lb) 45,700 cy

Future Extension - BP 44 - 43 (1,200 ft at 25 years)
- primary armor: 7,300 cy
- underlayer: 8,400 cy
- scour blanket: 8,900 cy

Repairs to Revetment and Scour Blanket - BP 56-44 (25th year)
- primary armor: 1,300 cy (includes Corps constructed portion only)
- scour blanket: 4,600 cy

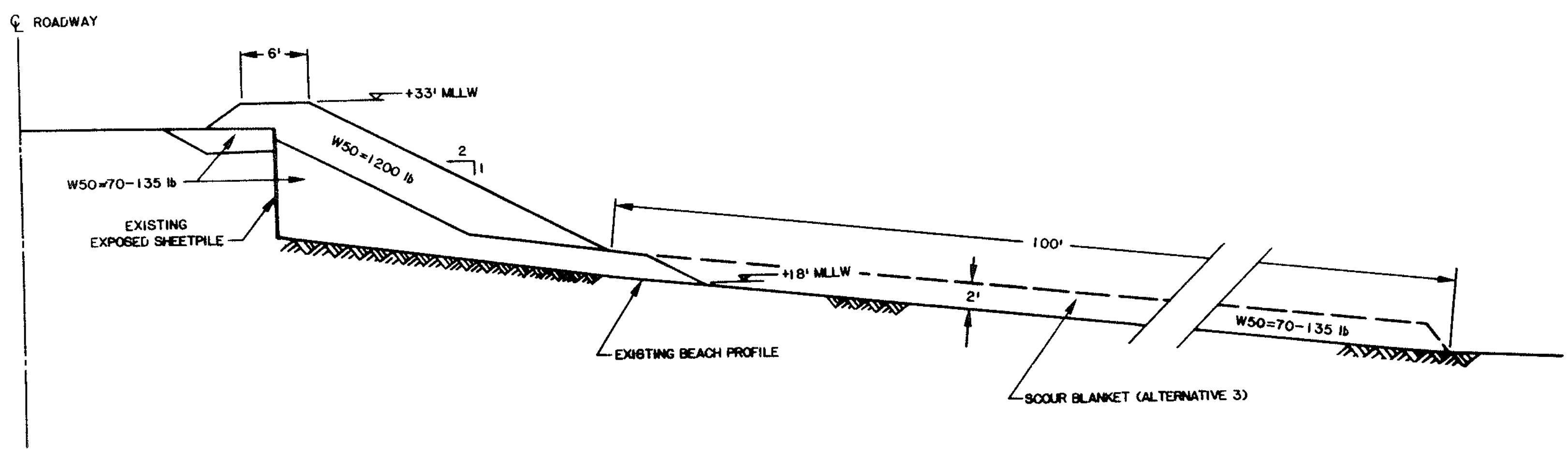

Figure 10 - Proposed revetment and scour blanket at Beach Profile 47

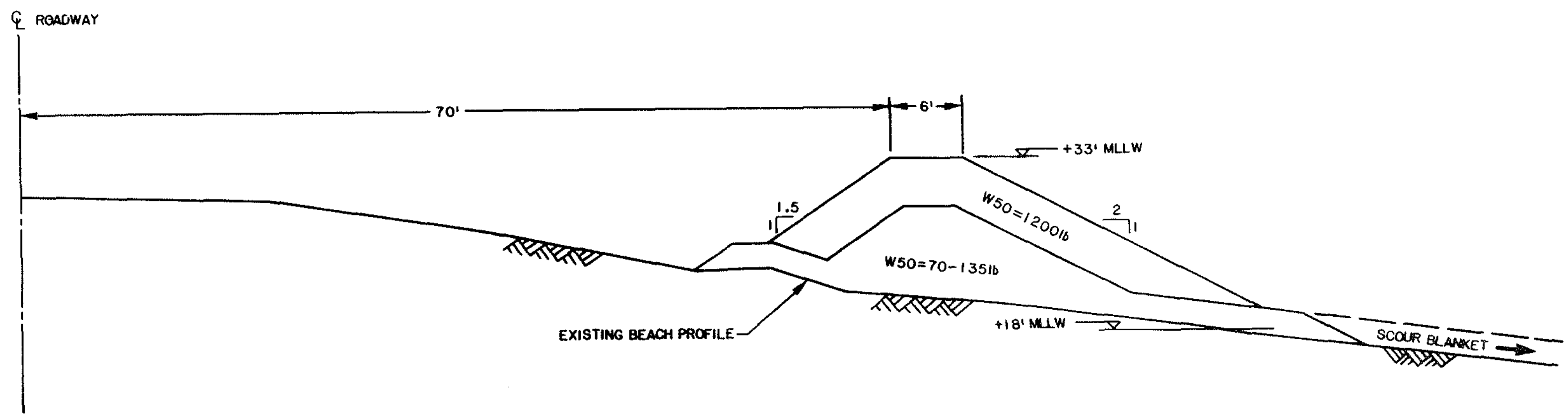

Figure 11 - Proposed revetment at Beach Profile 46

26. <u>Alternative 2 - Composite Beach Fill and Revetment Extension</u>: A plan involving a protective beach fill composed of two incremental fills of different materials was conceived as an artificial enhancement of existing natural conditions. This plan also included extension of the existing rubble revetment above high water, essentially in kind across the sheet-pile section in order to reduce the scour and overtopping problems in that area. A typical cross section is shown in Figure 12, superimposed on an August 1984 profile. The lower fill of sand, somewhat more coarse than the existing lower beach material, was designed to repair and elevate the existing low tide terrace from mid-tide to 0.0 ft MLLW at 800 ft off the roadway centerline. This fill would extend 7,900 ft along the affected area providing higher profiles with parallel contours, thus providing wave protection to the upper beach as well as attenuating the present divergence of wave energy. The upper fill was conceived as a more stable version of the existing high water beach, consisting of gravel and cobbles placed at a slope of 1:15 from the high tide level to intersect the lower fill around mid-tide. Upper beach slopes are now naturally on the order of 1:7 to 1:10. This fill was deemed to be necessary for the middle 6,400 ft of the critical area. Sources of borrow for both types of material could possibly be located at either the Archimandritof Shoals or the submerged delta-like accumulation offshore of Beluga Lake. A 1,100-ft extension of the rubble revetment from the top of the upper fill to +33 ft MLLW, as illustrated in Figure 12, would relieve the problems caused by the exposed sheet pile and protect the roadway from scour and excessive overtopping during severe storms. A renourishment interval for the lower fill was estimated at 11 years, assuming the fill material was somewhat more coarse than natural and at least as uniform. The following specifications apply to Alternative 2:

Lower Fill - Beach Profile (BP) 42 - 56 (7,900 ft)
- gravelly sand, D50 > 4 mm
- from existing profile at +10 ft MLLW to 0.0 ft MLLW at 800 ft off the roadway centerline

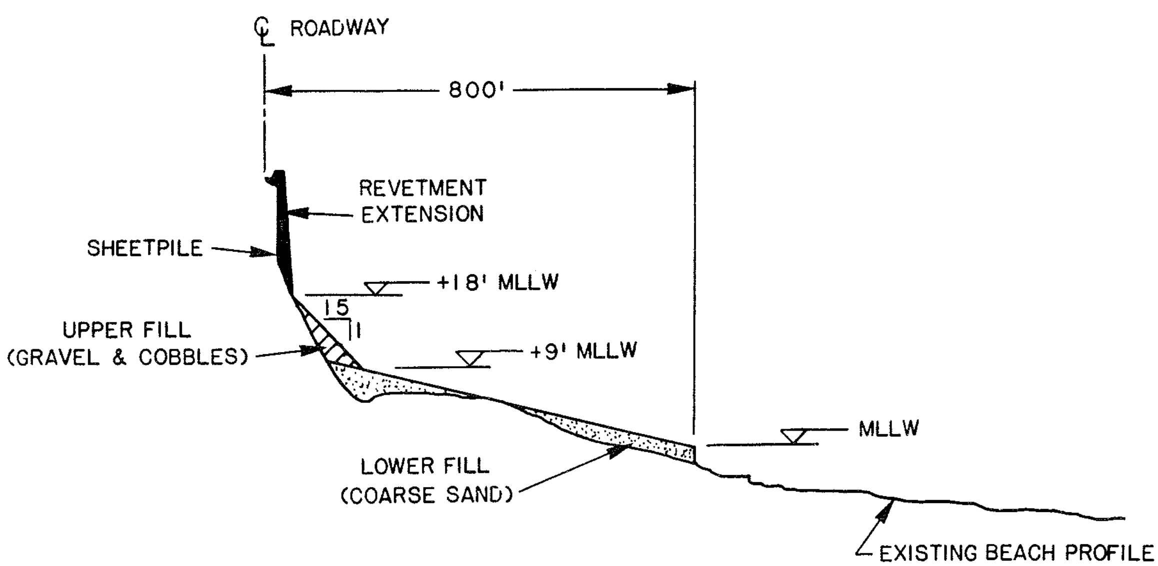

Figure 12 - Typical cross-section of Alternative 2 composite beach fill with revetment extension

- placed volume: 329,600 cy, including a 10 percent allowance for initial losses

Upper Fill - BP 43 - 55 (6,400 ft)
- gravel and cobbles, D50 > 50 mm
- from +18 ft MLLW on the existing profile at a slope of 1:15 to intersect the lower fill
- placed volume: 67,300 cy, including a 10 percent allowance for initial losses

Revetment Extension - BP 49A - 46 (1,100 ft)

- primary armor: graded quarrystone (W50 = 1,200 lb) 4,800 cy
- underlayer: graded quarrystone (W50 = 70-135 lb) 6,600 cy

Renourishment - Lower fill only, 329,600 cy every 11 years

27. Alternative 3 - Uniform Beach Fill and Revetment Extension: This alternative beach-fill plan was conceived to accommodate the likelihood of limited choices among borrow areas. The fill material was assumed to be a widely graded "glacial till" mix of grain sizes but with a median diameter of at least 4 mm. The fill would be placed from high tide (+18 ft MLLW) out to about the middle of the existing low tide terrace, as illustrated in Figure 13. This arrangement would presumably adjust rapidly to a transition of slopes resembling the natural profile, with the coarser components armoring the upper slope and the finer components spreading out over the low tide terrace. Renourishment of this beach fill plan was assumed to be necessary after 80 percent of the original fill (the low tide terrace portion) had been lost, which was estimated to occur at 10-year intervals. An identical revetment extension to that proposed for Alternative 2 is also included in this plan. The specifications for Alternative 3 are:

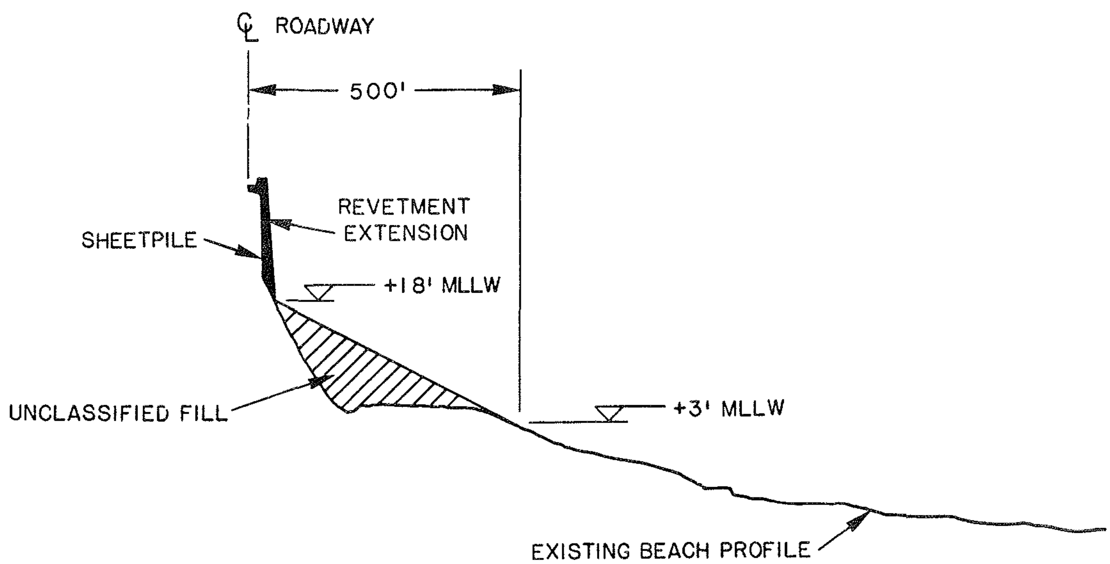

Figure 13 - Typical cross section for Alternative 3 uniform beach fill with revetment extension

Fill - BP 42 - 56 (7,900 ft)
- gravelly sand, widely graded, D50 > 4 mm
- from 18 ft MLLW on the existing profile to 3.0 ft MLLW or intersection of the existing profile at 500 ft off the roadway centerline
- placed volume: 350,000 cy, including a 10 percent allowance for initial losses

Revetment Extension - same specifications as Alternative 2

Renourishment - every 10 years, 280,400 cy

28. Evaluation of Alternatives: Pricing data and information about material sources were not available to CERC, so a comparative evaluation of the above alternatives is possible in this report only in terms of their effectiveness. They were all designed to be equally effective in protecting the roadway from further erosion in the vicinity of the existing revetment and sheet-pile section. The long-term response of the Spit to these plans cannot be quantitatively predicted without substantial additional data collection and analysis. The beach-fill plans are subjectively seen as having greater merit in that they prevent the loss of submerged land, while the revetment extension and scour blanket do so only to a much lesser extent. It is suggested in the interim that the three plans be considered equally effective in maintaining the roadway.

Conclusions

29. The following conclusions relate to CERC findings to date regarding the underlying nature of the coastal erosion, the confidence of those findings, and the apparent most effective means to actively respond to the erosion problem:

1. The winds, and consequently the wave climate, affecting Homer Spit are subject to strong orographic influences which at this point are poorly defined. Analysis of existing wind data and comparison of waves forecast from these data with limited measured wave data indicates agreement which is adequate for planning purposes. The wave climate along the western shore of the Spit appears to be milder than that experienced elsewhere on the Kenai Peninsula where more southerly exposure toward Shelikof Strait exists. The present estimates of deepwater wave characteristics, breaker characteristics and associated longshore transport rates are believed to be conservative.

2. The sediment transport analysis of this study was based primarily on the wind and wave analyses discussed above, since survey information (successive beach profiles) to establish actual erosion rates was not available. The numerical modeling of nearshore wave transformation was performed only for a condition with the water surface at MLLW; therefore, subjective judgments were made as to how these predictions might relate to higher water levels. The beach profiles plotted from August 1984 data showed some recognizable characteristics which could be related to the other field observations, the wave transformation analysis, and the analysis of beach material data. The apparent existence of a zone of refractive wave energy divergence at Homer is a common situation at many beaches with similar erosion problems. The

experiences of erosion control measures undertaken in similar situations is valuable in eliminating options which could result in adverse consequences, such as vertical seawalls, beach groins, and offshore breakwaters.

3. The possibility of a protective beach fill was the most favorable option in the opinion of all the CERC specialists involved in the study, but the potential high cost of placement and later renourishment in Alaskan conditions was recognized. A minimally complex beach-fill plan was proposed as an alternative to a more detailed plan with these conditions in mind. A more traditional third option of an extensive rubble revetment was also proposed, though this alternative would allow loss of submerged lands in an amount that is unpredictable without additional data and analysis. The roadway providing access to the developments at the tip of the Spit could be maintained for at least 50 years by each of the proposed alternatives.

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APPENDIX A: Wind Data Analysis and Wave Forecast

INTRODUCTION

1. This appendix describes the methods used to analyze the frequency, duration, and direction of measured wind data in Lower Cook Inlet and to present the preliminary results of the analysis. Wind data were available from three sources: Homer Spit, Homer Airport, and National Data Buoy Office (NDBO), buoy EB 46007. Each data set was adjusted and summarized. The summaries were compared visually and statistically to determine which set or combination of sets would give the most reliable wave prediction results. Wave heights, periods, and directions were calculated from the wind summaries using a fetch-limited wave generation model.

MEASURED WIND DATA

2. Homer Spit: The anemometer on Homer Spit is located at the harbor master's office near the end of the spit (Figure 3, main report). The elevation of the anemometer is approximately 25 ft. Hourly averages (readings taken once a second averaged over 1 hr) from February 1965 through January 1982 were available from the spit site. This data set was acquired in two parts: (1) February 1965 through August 1973 and (2) August 1973 through January 1982. In the first data set (2/65 - 8/73), 55 percent of the data was missing, leaving 30,894 data points. In the second data set (8/73 - 1/82), a 20-mph threshold was applied to the data when it was digitized, so no windspeeds less than 20 mph were recorded. This resulted in a net loss of 97 percent of the second data set, leaving 2,437 data points.

3. The data were adjusted using the method presented in the SPM (1984).* The adjustments included:

a. Correction to 10-m level.

b. Adjustment of overland readings to overwater readings.

c. Correction for instability due to air-sea temperature differences for directions where the fetch is greater than 10 miles (an unstable condition was assumed, since no temperature data were available).

d. Correction for nonconstant coefficient of drag.

These corrections were made so that the wind data could be applied directly to wave forecasting curves and compared to the other data sets. The adjusted data should not be considered as actual wind speeds, but rather as "wind stress factors", since the adjustment for nonconstant coefficient of drag has been included.

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* All references cited in the Appendixes can be found in the References at the end of the main report.

4. The distribution of the hourly winds with respect to direction is shown as a wind rose (Figure A-1). The wind rose shows the distribution of winds in 16 directional sectors as a percent of all winds. The bars in each direction are divided into 10-mph intervals. Only the data from February 1965 through August 1973 are included in the wind rose.

5. Homer Airport: A National Weather Service anemometer is located at Homer Airport, north of Homer Spit (Figure 3, main report). The elevation of the anemometer is 30 ft. One minute averages were available hourly from January 1951 through December 1982. Nineteen percent of the data set was missing, leaving 227,207 data points.

6. The data were also adjusted using the method presented in the SPM (1984). The adjustments included:

a. Correction to 1-hr duration.

b. Correction to 10-m level.

c. Adjustment of overland readings to overwater readings.

d. Correction for instability due to air-sea temperature differences for directions where fetch is greater than 10 miles (an unstable condition was assumed, since no temperature data were available).

e. Correction for nonconstant coefficient of drag.

The corrections to adjust the windspeed to overwater values (c and d) are inappropriate for winds coming from inland, but these directions account for only a small percent of all winds.

7. The distribution of hourly winds with respect to direction is shown as a wind rose (Figure A-2). The wind rose shows the distribution of winds in 16 directional sectors as a percent of all winds. The bars in each direction are divided into 10-mph intervals.

8. NDBO Buoy: A NOAA/NDBO buoy, EB-46007, was located in lower Cook Inlet from 1977 to 1979 at the position shown in Figure 1 of the main report. The elevation of the anemometer was not constant (10 m from 25 June 1977 to 5 March 1978, 5 m from 5 March 1978 to 31 March 1978, 10 m from 31 March 1978 to 16 August 1978, and 5 m from 16 August 1978 to 15 June 1979), so the correction factor was recalculated for each reading to adjust all wind conditions to a constant 10-m elevation. Eight and one-half-minute averages of windspeed every 3 hrs from June 1977 through June 1979 were available from the buoy. Thirty-eight percent of the data set was missing, leaving 3,564 data points.

9. These data were also adjusted using the method presented in the SPM (1984). The adjustments included:

a. Correction to 1-hr duration.

b. Correction to 10-m level.

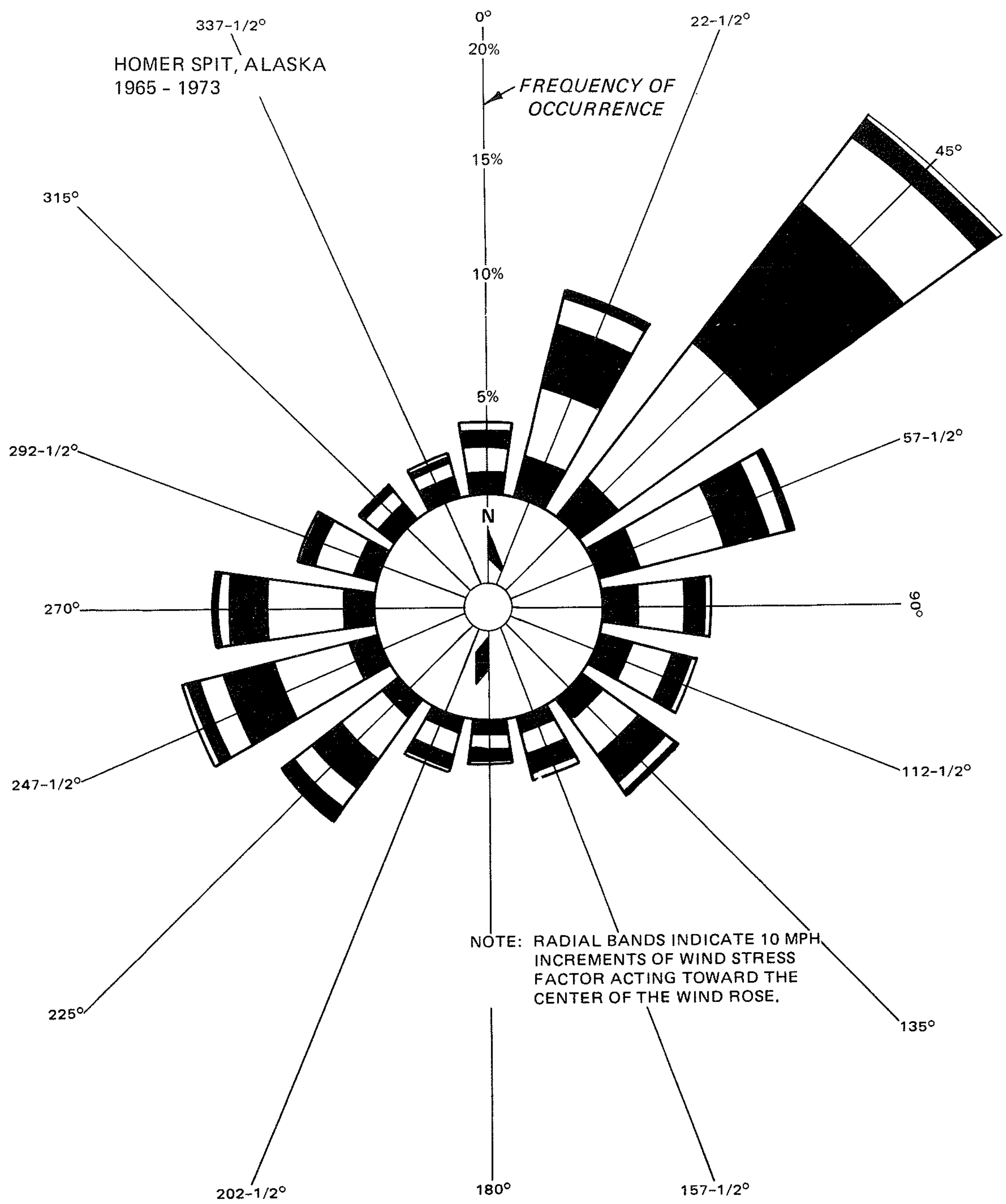

Figure A-1. Wind rose for Spit anemometer, Homer, Alaska

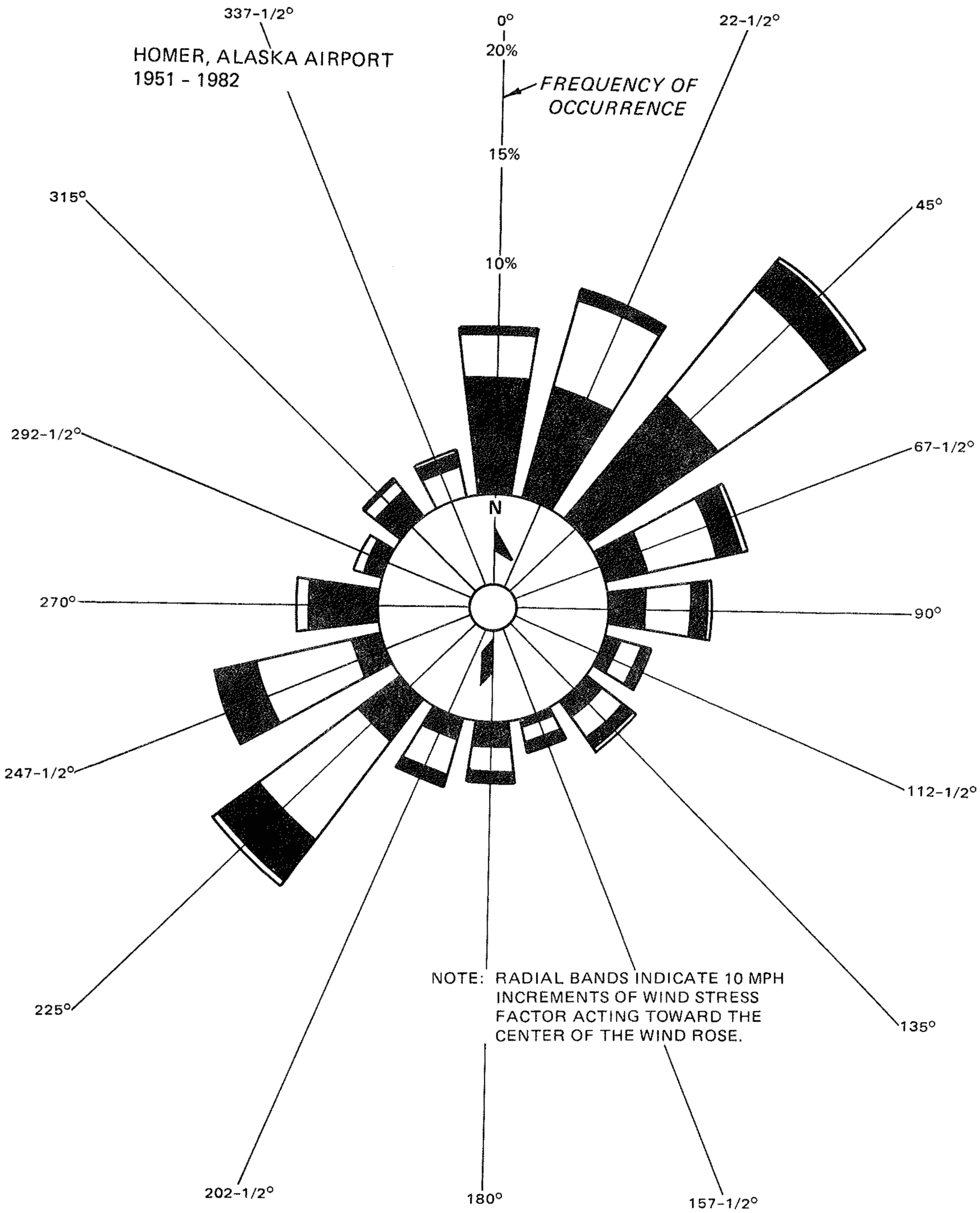

Figure A-2. Wind rose for airport anemometer, Homer, Alaska

c. Correction for instability due to air-sea temperature differences where the fetch is greater than 10 miles (an unsteady condition was assumed, since no temperature data were available).

d. Correction for nonconstant coefficient of drag.

10. The distribution of the hourly winds with respect to direction for the NDBO buoy is shown as a wind rose in Figure A-3. The wind rose shows the distribution of winds in 16 directional sectors as a percent of all winds. The bars in each direction are broken into 10-mph intervals.

COMPARISON OF WIND DATA

11. The winds in Lower Cook Inlet are orographically funneled through two axes. One axis runs along Cook Inlet and Shelikof Strait (northeast-southwest), and the second axis runs from Kennedy and Stevenson entrances to Kamishak Gap (east-west), according to Macklin et al (1980). This is evident in the wind rose for the NDBO buoy (Figure A-3). In the Kachemak Bay area, where Homer Spit is located, katabatic flows off the glacier on the northeast end of the bay dominate the wind patterns (Figures 1 and 2, main report). But, according to Macklin, et al. (1980) these winds erode very quickly and are seldom seen more than 20 km offshore. The winds entering Kachemak Bay from Lower Cook Inlet appear to be orographically funneled into the bay. To adequately describe all wind conditions in Lower Cook Inlet by measurements at one point that has been shown to be biased by orographic effects is a difficult problem. The winds entering Kachemak Bay from Lower Cook Inlet are of primary interest in this study. These winds would be responsible for locally generated waves arriving at Homer Spit.

12. Before comparisons were made between data sets, the data were paired, matching date and time (within 1 hr). The resulting sets of paired observations were: spit-airport 1965-1973, buoy-airport 1977-1979, buoy-spit 1977-1979. The buoy-spit combination had limited value because of the paucity of the spit data after 1972. Wind rose summaries (Figures A-4, A-5, A-6 and A-7) were plotted for each wind data source from the data points which matched those of another source. The titles and captions of the four figures indicate which data source is represented and which other data source had matching wind data. The matched data sets were also compared as time-histories and by linear regression.

13. Spit - Airport: The spit and airport anemometer locations are within 5 miles of each other. In general, the spit anemometer has better exposure to winds in Lower Cook Inlet and outer Kachemak Bay because it is farther from the local effects of the mountains surrounding Kachemak Bay. The airport anemometer has a longer, more continuous data record. This makes the airport data more statistically reliable (the data recorded in the shorter, less continuous spit record could be unusually high or low). The wind roses from the spit-airport pairing show similar distributions in terms of wind direction (Figures A-4 and A-5), but the airport wind speeds are lower. The lower airport wind speeds could be caused by sheltering from the nearby mountains. Another contributing factor may relate to the correction of spit winds from overland to overwater (because of the narrowness of the spit) and for air-sea

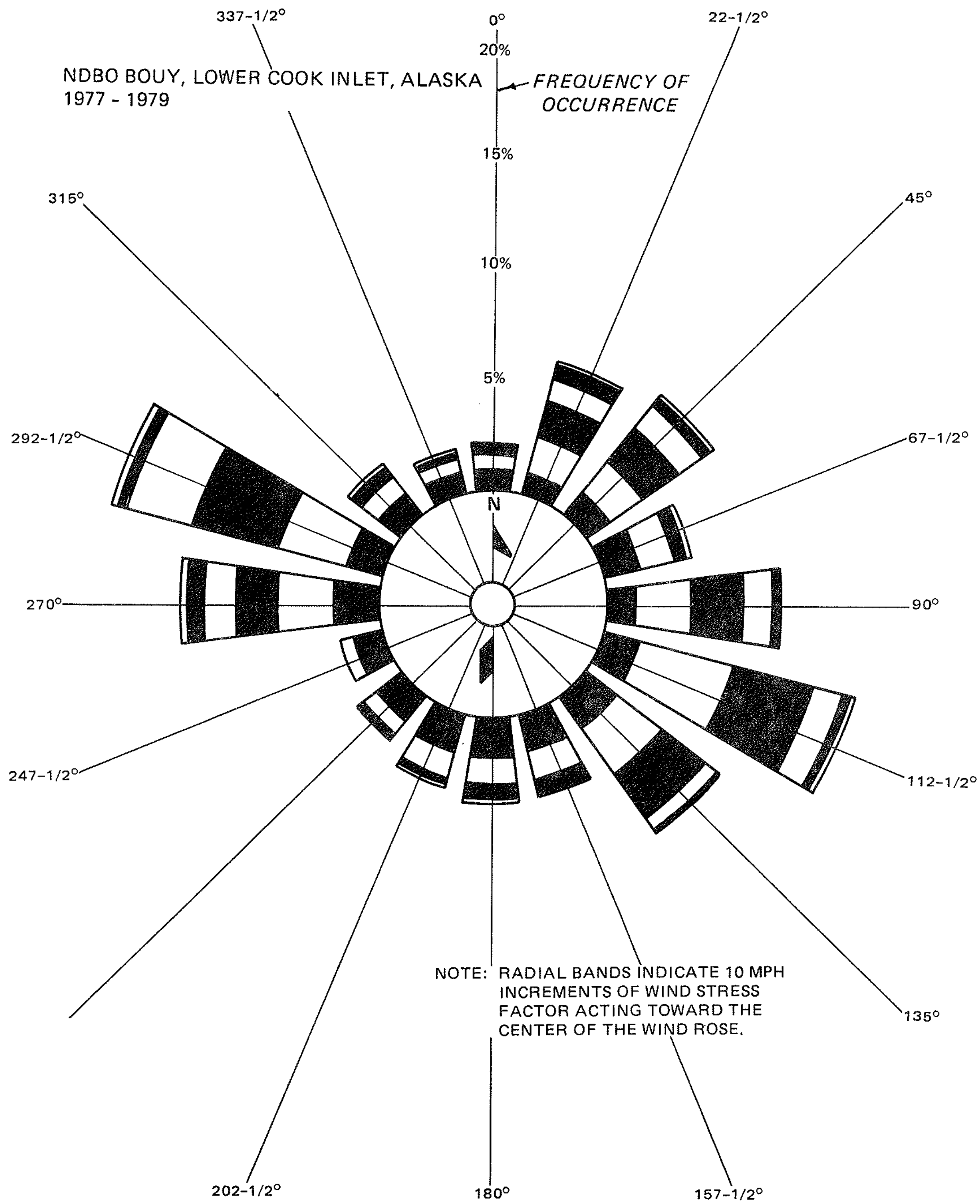

Figure A-3. Wind rose for National Data Buoy Office, Buoy EB 46007, Cook Inlet, Alaska

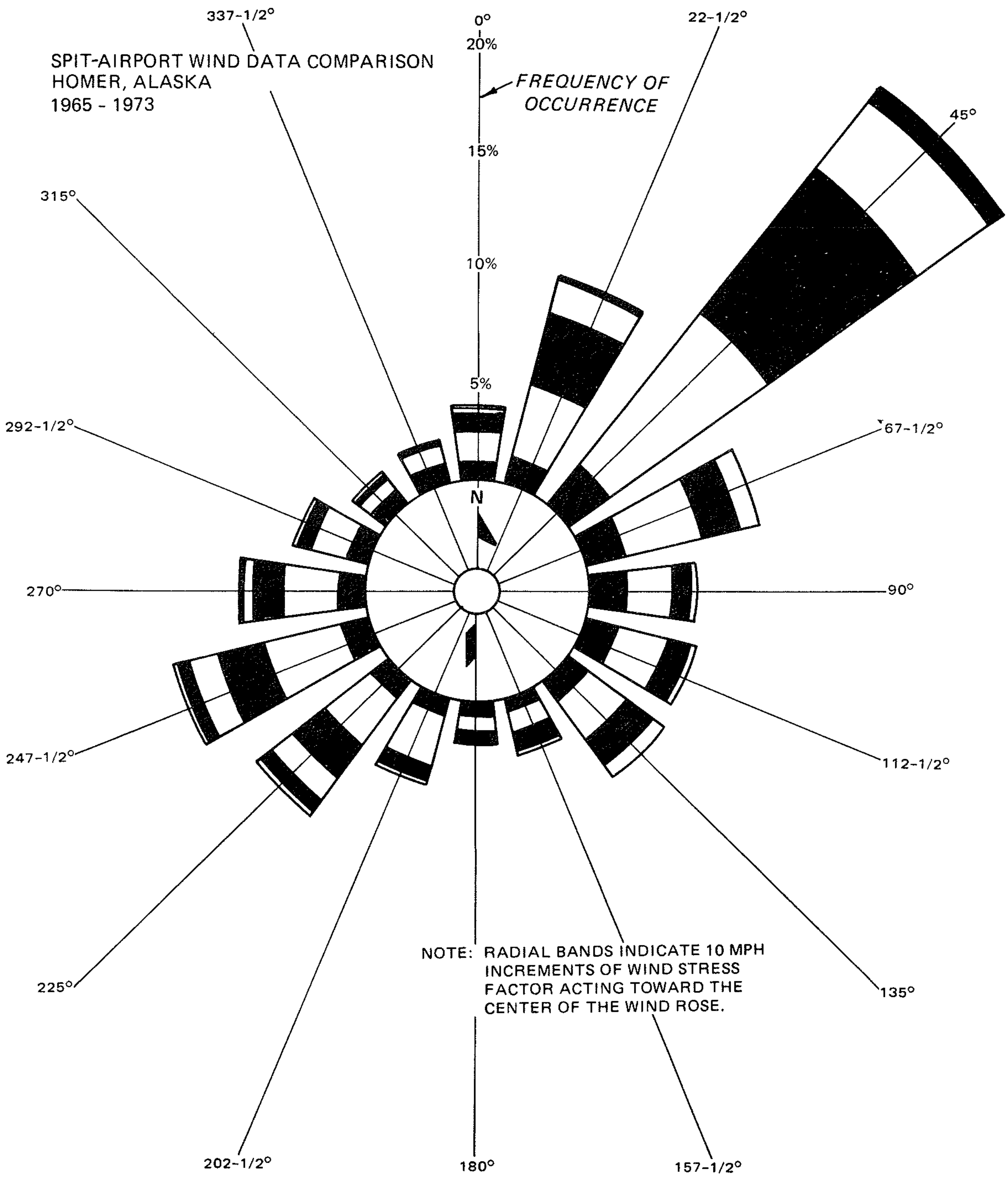

Figure A-4. Wind rose of Spit anemometer data for which there were concurrent data from the airport anemometer, Homer, Alaska

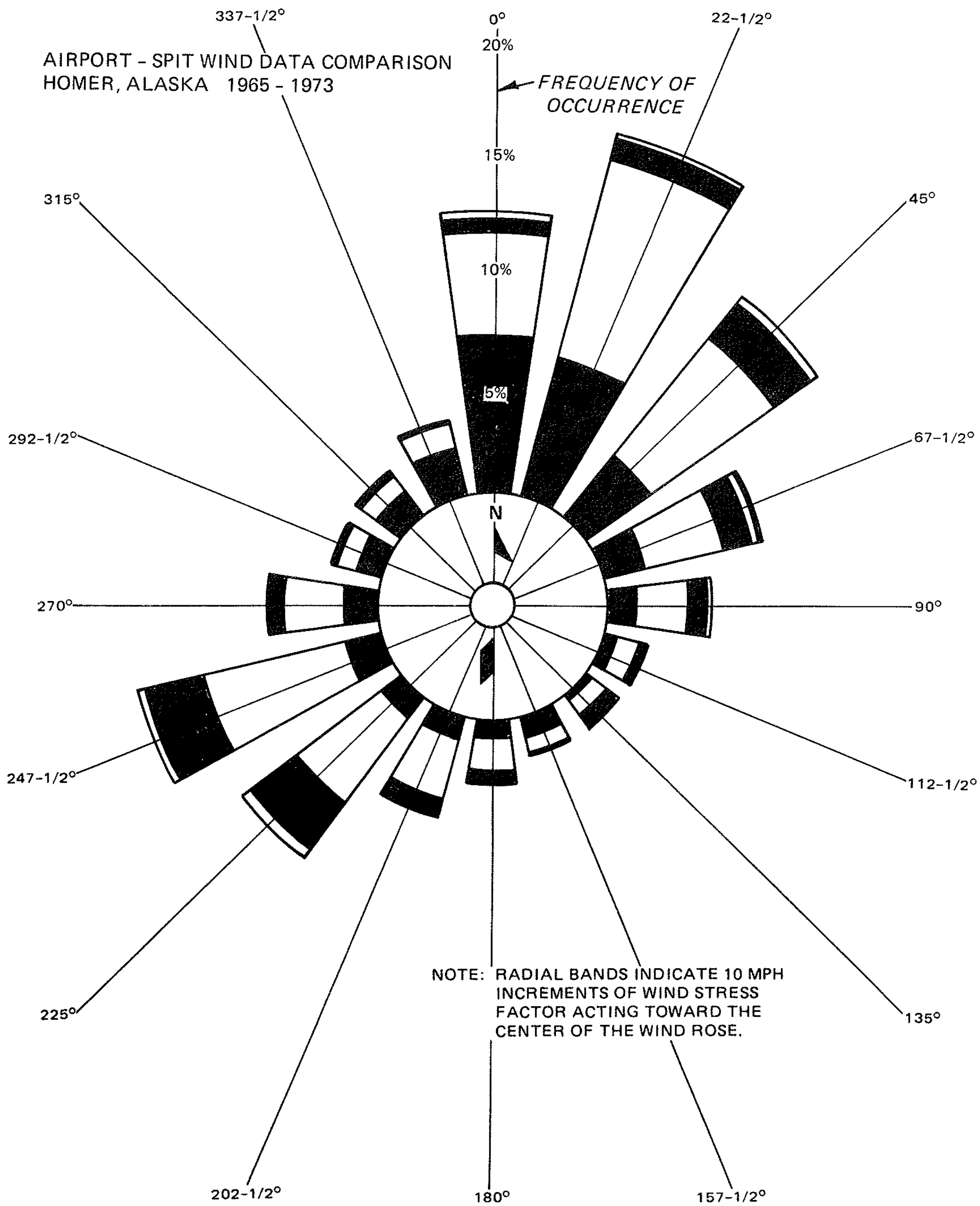

Figure A-5. Wind rose of airport anemometer data for which there were concurrent data from the Spit anemometer, Homer Alaska

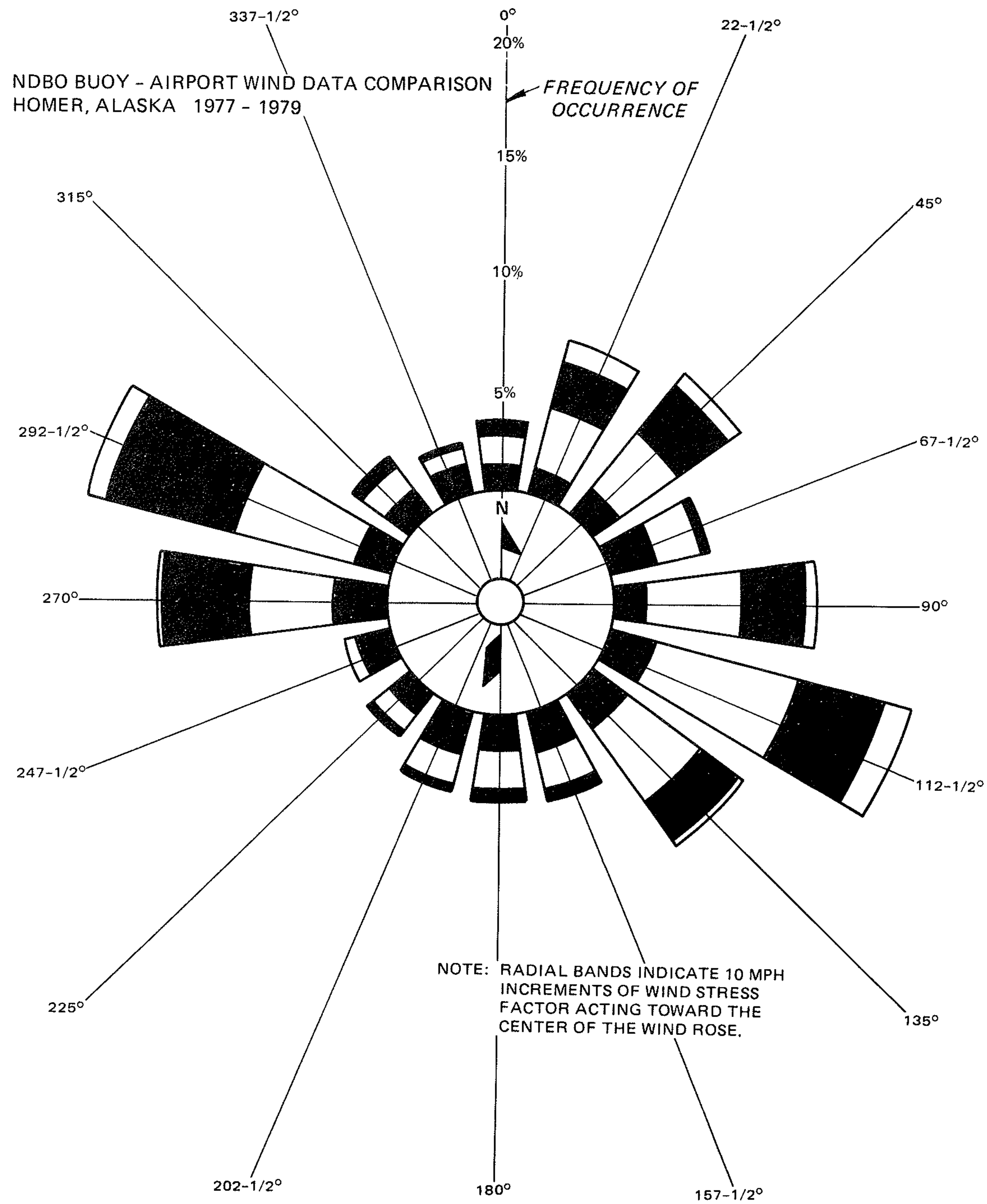

Figure A-6. Wind rose of National Data Buoy Office buoy data for which there were concurrent data from the airport anemometer, Homer, Alaska

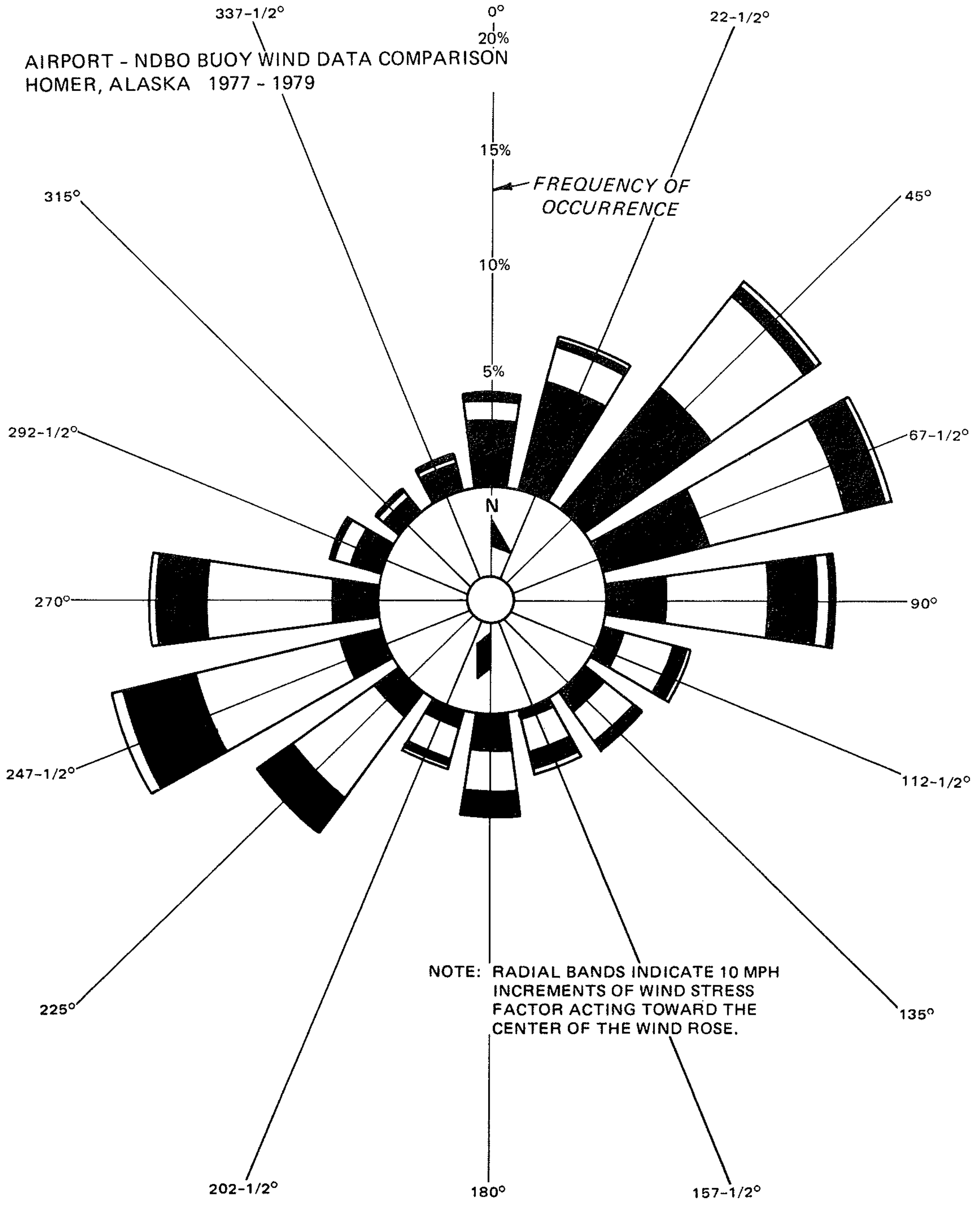

Figure A-7. Wind rose of airport anemometer data for which there were concurrent data from the National Data Buoy Office buoy temperature differences. The mean wind speeds are as follows:

	MEAN	STD DEV
SPIT	19.0 mph	9.8 mph
AIRPORT	14.6 mph	6.4 mph

A linear regression analysis with spit wind speed as the independent variable (X) and airport wind speed as the dependent variable (Y) gave the following results:

$$A = 13.0$$
$$B = 0.081$$
$$\text{where} \quad Y = A + BX$$

correlation coefficient = 0.015

There was no meaningful correlation between spit and airport winds. This is also shown in a scatter plot (Figure A-8) of spit and airport wind speeds which would plot as a 45-deg line for a correlation coefficient of 1.00. Time-histories of the spit and airport wind speeds and directions for storm events are shown in Figures A-9 and A-10. The time histories show fairly good agreement in wind direction but poor agreement in wind speed. The airport wind speeds tend to be lower than the spit wind speeds, and the airport data misses the storm peaks seen at the spit by 20 to 30 mph. This is why the correlation is so poor. Linear regressions were also run on subsets of the data, including windspeeds greater than 15 mph, wind speeds greater than 20 mph, wind directions between 236 deg and 304 deg (opening to Lower Cook Inlet), and wind directions between 34 deg and 79 deg (opening to Kachemak Bay), but the correlation coefficient remained below 0.05 in all cases. Two possible explanations for the differences in the wind speeds at the closely spaced anemometers are:

a. The airport anemometer is very sheltered and/or it responds to very localized topographical and thermal effects.

b. The spit anemometer gives inconsistent results. The spit data record has many gaps, which raises questions about how well the anemometer was maintained.

No definitive explanation can be made without additional meteorological stations in the area.

14. Buoy - Airport: The NDBO buoy is positioned in Lower Cook Inlet so that it is affected by the major wind patterns of the inlet (Cook Inlet to Shelikof Strait, and Kennedy and Stevenson entrances to Kamishak Gap) instead of the local effects of Kachemak Bay, like the airport or spit anemometers. The wind roses (Figures A-6 and A-7) show very different directional distributions for the buoy and the airport. The mean wind speeds are as follows:

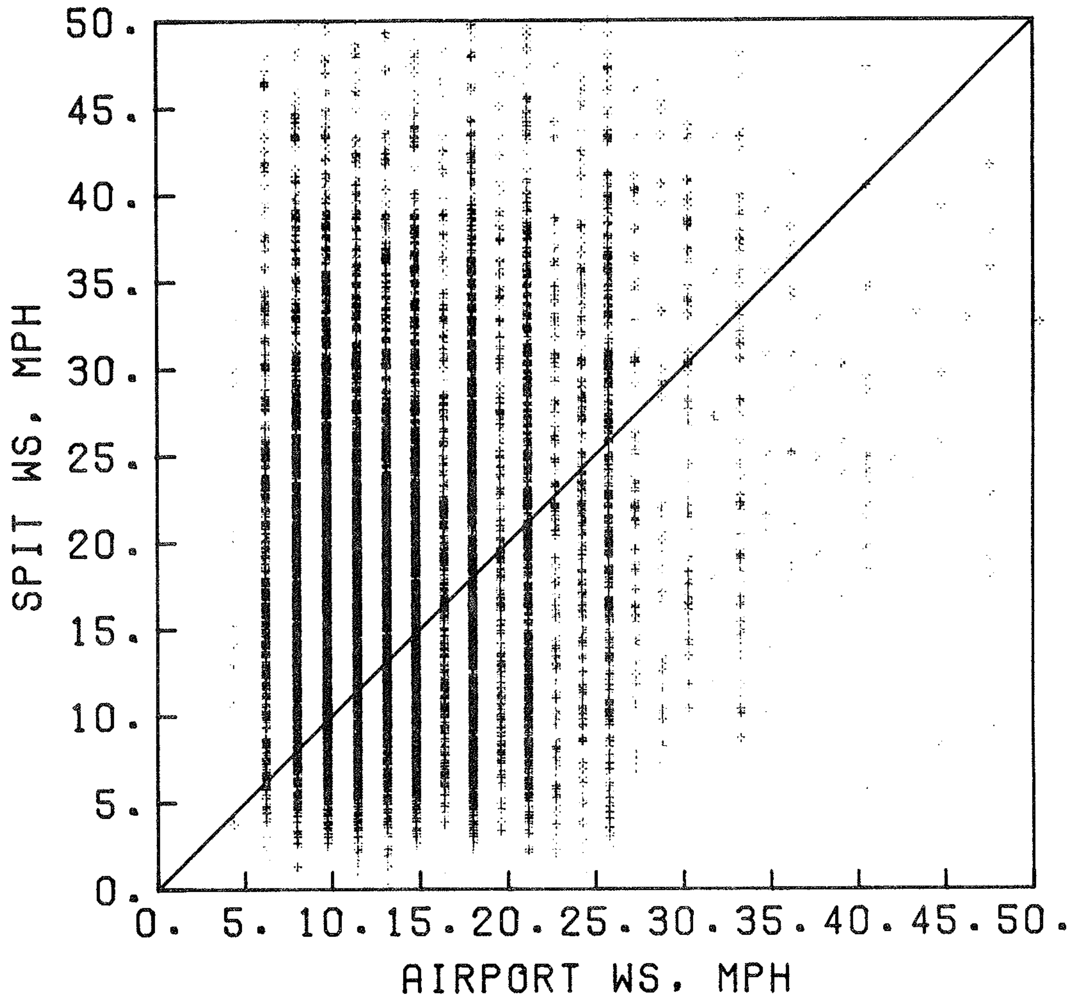

Figure A-8. Scatter plot of paired spit and airport observations

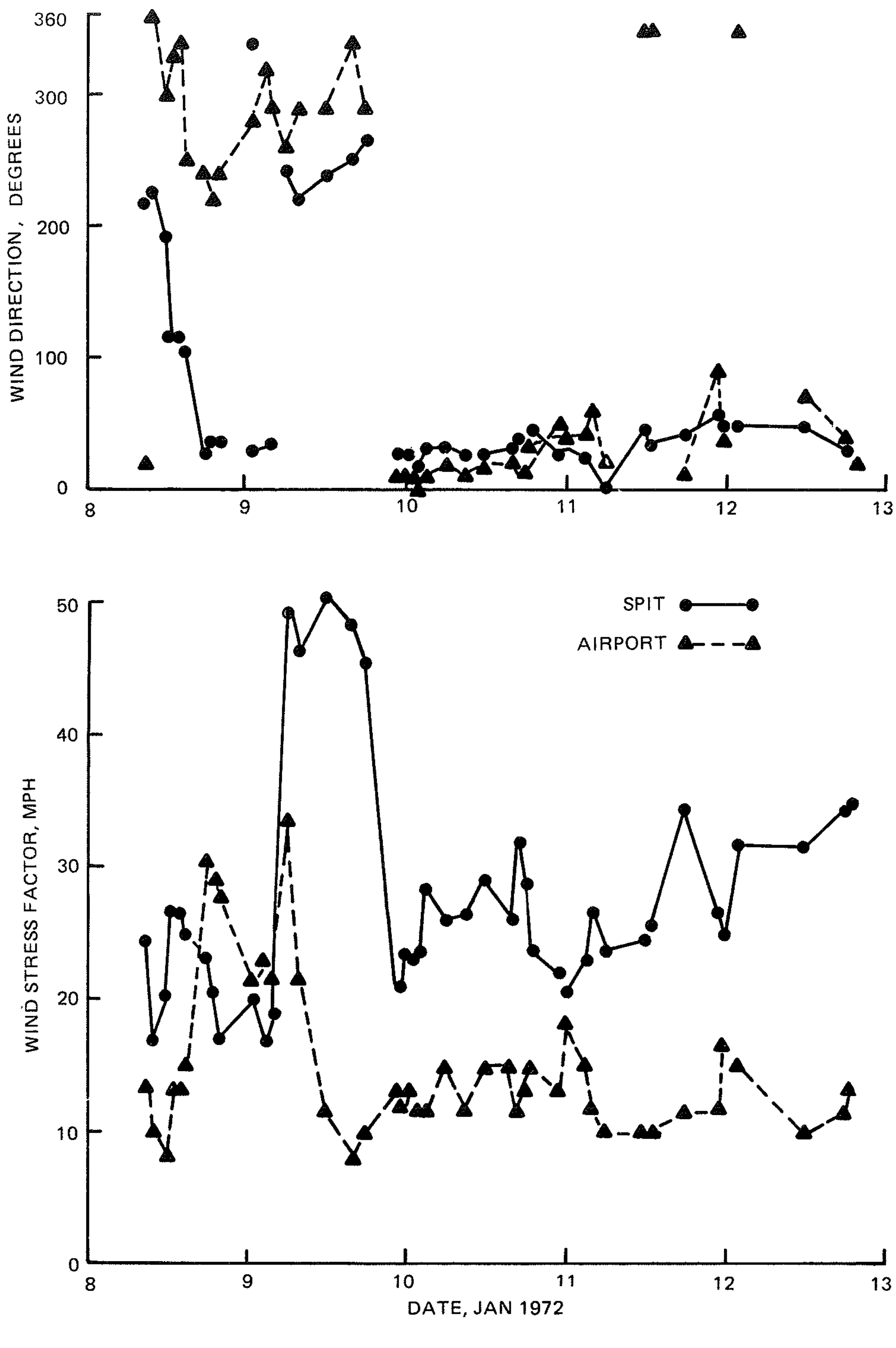

Figure A-9. Comparison of time-histories from the Spit and airport anemometers, Homer, Alaska

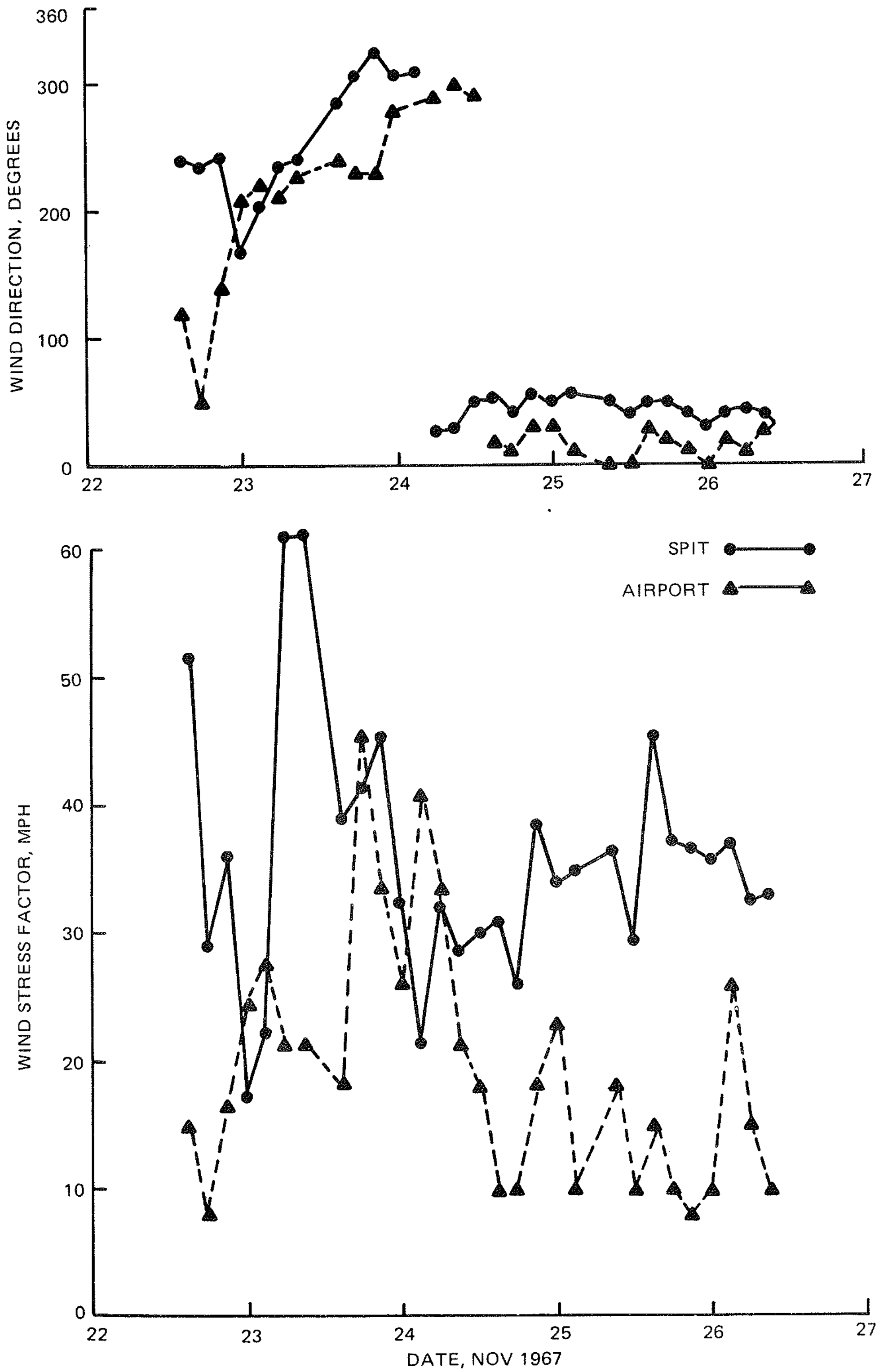

Figure A-10. Comparison of time-histories from the Spit and airport anemometers, Homer, Alaska

	MEAN	STD DEV
BUOY	16.4 mph	8.2 mph
AIRPORT	14.3 mph	6.3 mph

A linear regression analysis with buoy wind speed as the independent variable (X) and airport wind speed as the dependent variable (Y) gave the following results:

$$A = 11.0$$
$$B = 0.148$$
$$\text{where } Y = A + BX$$

correlation coefficient = 0.036

This result indicates there is no correlation between the buoy and airport winds. This is also shown in a scatter plot (Figure A-11). Time-histories of the buoy and airport wind speeds and directions are shown in Figures A-12 and A-13. The time-histories show poor agreement in wind speed and direction. The wind directions differ by as much as 180 deg during storm events for periods of several hours. This was also shown by Macklin et al (1980). Wind speeds also show no relation to each other. In this case, the lack of correlation is not as surprising as in the Spit-airport case because of the katabatic effects and differences in orographic funneling in Kachemak Bay that would not affect the buoy.

15. Buoy - Spit: This pairing has the same location effects as the buoy-airport data but includes a much smaller data set because of the paucity of spit data. The data are also biased high because of the 20-mph threshold applied on the Spit data. The mean wind speeds are as follows:

	MEAN	STD DEV
BUOY	22.1 mph	9.1 mph
SPIT	36.3 mph	8.1 mph

A linear regression analysis with the buoy wind speed as the independent variable (X) and the spit wind speed as the dependent variable (Y) gave the following results:

$$A = 35.7$$
$$B = 0.025$$
$$\text{where } Y = A + BX$$

correlation coefficient = 0.001

This result indicates there is also no correlation between the buoy and spit winds. This is also shown in a scatter plot (Figure A-14). The lack of correlation is not surprising, as in the buoy-airport case.

16. The lack of correlation between the NDBO buoy and the Spit or airport shows that wind conditions at the buoy site in Lower Cook Inlet do not

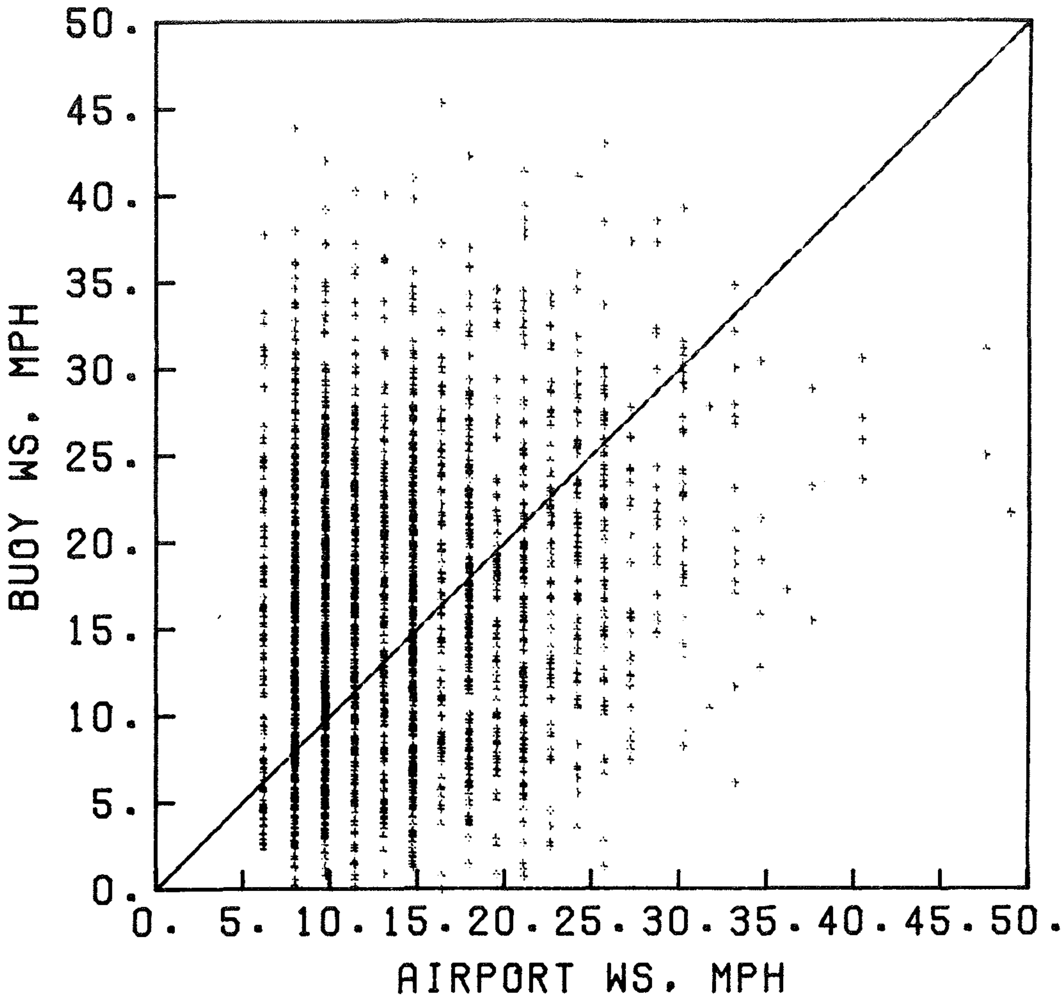

Figure A-11. Scatter plot of paired buoy and airport observations

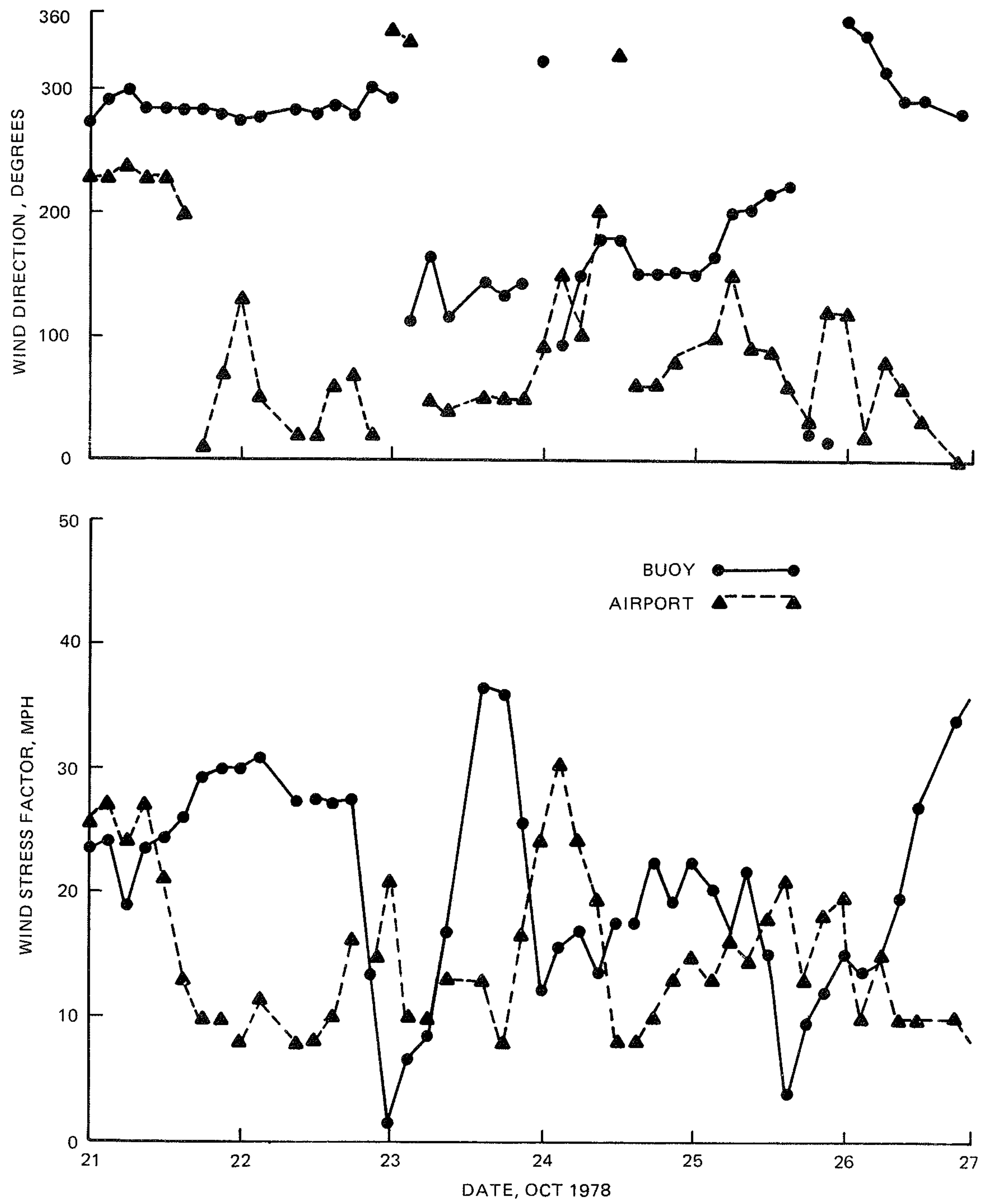

Figure A-12. Comparison of time-histories from the National Data Buoy Office buoy and airport anemometers, Homer, Alaska

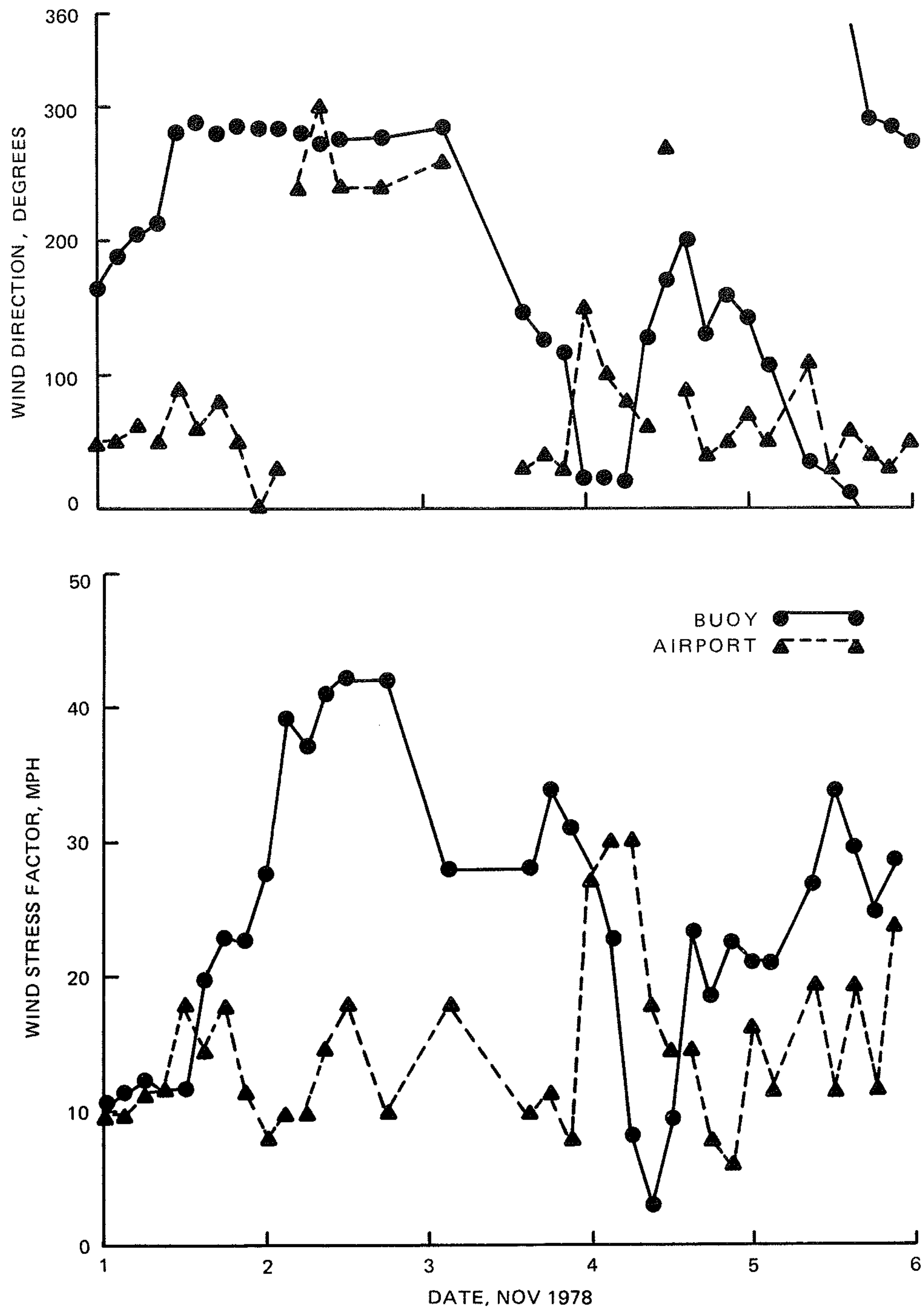

Figure A-13. Comparison of time-histories from the National Buoy Office buoy and airport anemometers, Homer, Alaska

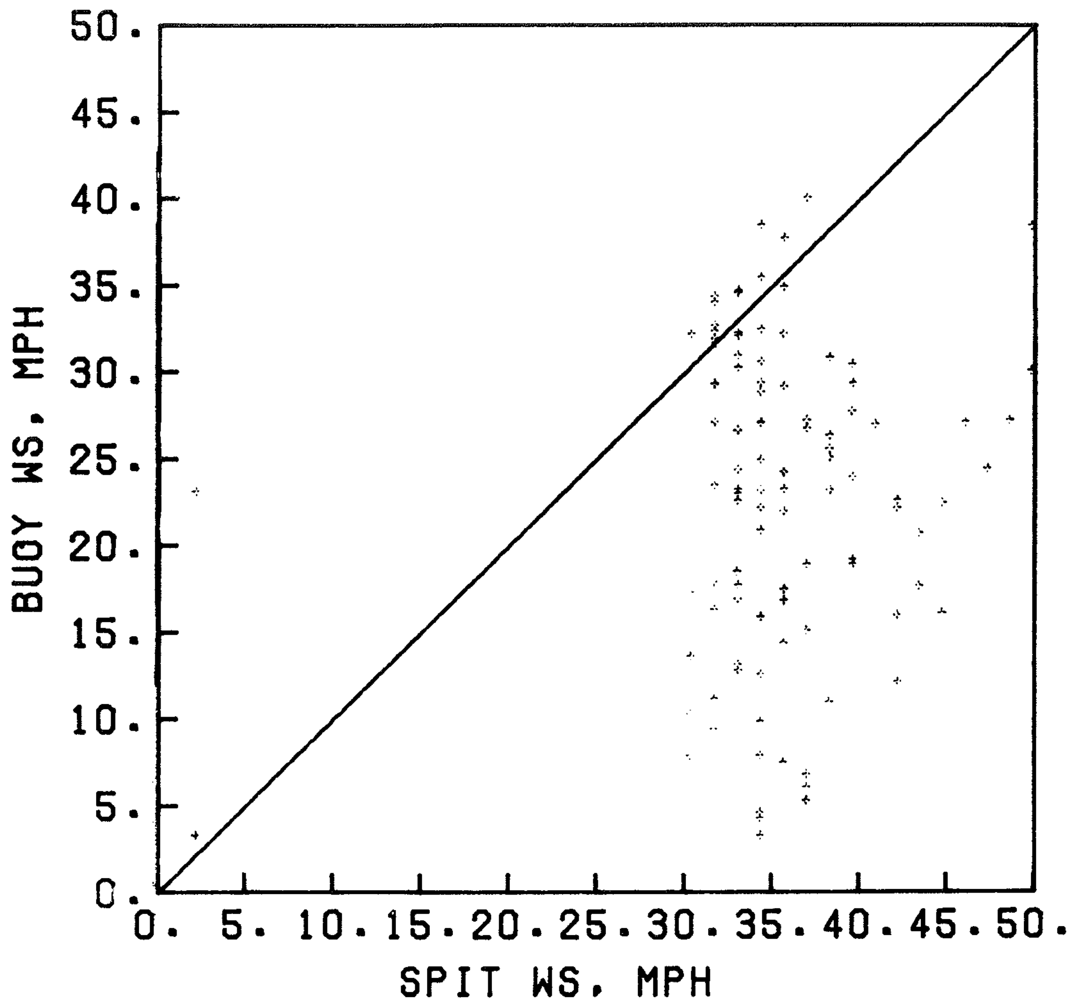

Figure A-14. Scatter plot of paired buoy and spit observations

represent what is happening in Kachemak Bay and vice versa. Therefore, synoptic scale events and geostrophic flows do not describe local wind conditions in Cook Inlet. Standardized techniques will not adequately resolve the subscale meteorological features found in Cook Inlet. In order to resolve localized wind fields in outer Kachemak Bay and Lower Cook Inlet opposite Homer Spit, additional meteorological stations would be needed in and around outer Kachemak Bay and adjacent Lower Cook Inlet.

WAVE FORECAST

17. A simplified technique was used in this preliminary study to calculate gross estimates of wave height, period, and direction from the single point sources of wind at Homer Spit and Homer Airport. For a first approximation it was assumed that all wind conditions existing at Homer, Alaska, are present in the entire region of Lower Cook Inlet. This approach was expected to provide

an overestimate of existing wave conditions since the winds well offshore from Homer are generally not blowing toward Homer Spit. Without additional wind estimates within Lower Cook Inlet, no conclusion about the reliability of Homer Spit and Homer Airport winds can be made. Follow-up work after this initial study, based on empirical consideration of wave measurements being taken in Lower Cook Inlet by NPA, is expected to provide significantly improved wave estimates.

18. Wave heights, periods, and directions were calculated from the Spit and airport wind roses using the fetch-limited JONSWAP equation from the Shore Protection Manual (1984). Since the fetch lengths (Table A-1) and wind directions are essentially the same for the Spit and the airport, the only differences in the wave hindcast results are the probability distributions. The results of these wave forecasting computations are given in Tables 1, 2, and 3 of the main report.

TABLE A-1 - Fetch Lengths

DIRECTION (deg)	FETCH (miles)
281.25 - 303.75	46.7
258.75 - 281.25	61.9
236.25 - 258.75	77.7

19. Measured wave data from Kachemak Bay and spit wind data for February through October of 1984 were available to test this method. Airport wind data were not available. Wind data were available hourly from the spit anemometer. Wave data were available every 3 hrs from an accelerometer wave buoy in Kachemak Bay (59° 36.2'N, 151° 32.4'W). Wind data were averaged over a 3-hr period prior to each wave gage reading. Wave heights and periods were calculated from the average wind speeds and directions using the fetch-limited JONSWAP equation for the wave directions approaching Homer Spit from Cook Inlet. These calculated wave heights and periods were compared with the wave heights and periods measured by the wave rider buoy at corresponding times. A scatter plot of the calculated vs. observed wave heights is shown in Figure A-15. The mean wave heights are as follows:

	MEAN	STD DEV
CALCULATED WAVE HEIGHT (feet)	3.03	2.07
OBSERVED WAVE HEIGHT (feet)	1.71	1.39

A linear regression analysis with the observed wave height as the independent variable (X) and the calculated wave height as the dependent variable (Y) gave the following results:

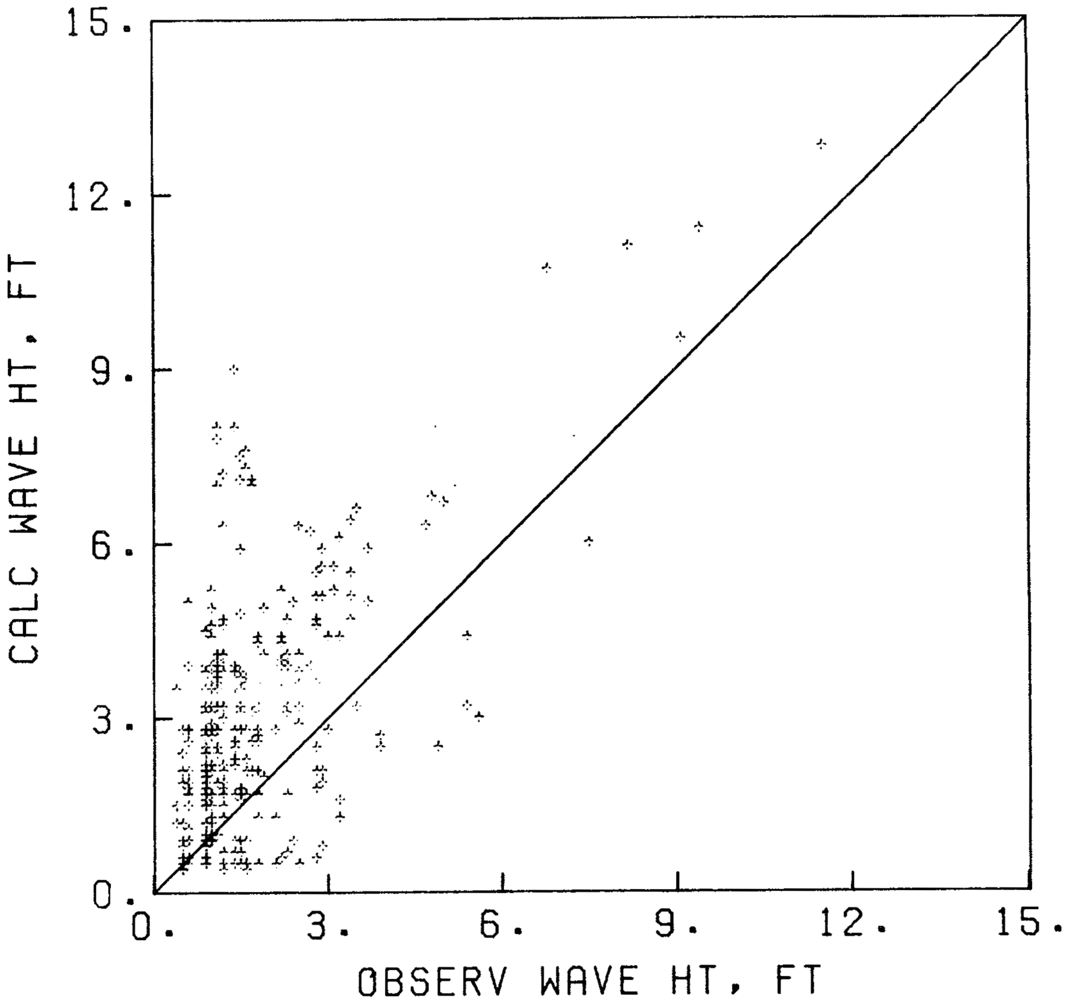

Figure A-15. Scatter plot of calculated versus measured waves

A = 1.568
B = 0.856
where Y = A + BX

correlation coefficient = 0.577

The calculated wave heights tend to overestimate the actual wave heights. The mean wave periods are as follows:

	MEAN	STD DEV
CALCULATED WAVE PERIOD (sec)	4.91	1.24
OBSERVED WAVE PERIOD (sec)	4.18	1.99

A linear regression analysis comparing wave periods, with the observed wave

APPENDIX B: Wave Transformation Analysis

INTRODUCTION

1. This appendix describes the method used to transform deepwater wave conditions in outer Kachemak Bay to breaking conditions at Homer Spit, Alaska. The breaking conditions were then used to estimate longshore sediment transport.

2. The deepwater wave conditions in Kachemak Bay were estimated using the fetch-limited Jonswap equation (Shore Protection Manual, 1984) with measured wind conditions and fetch lengths. Two wind data sources were available: (a) an anemometer at Homer Airport, Homer, Alaska, and (b) an anemometer located at the harbor master's office on Homer Spit (Figure 3, main report). Previously, the two wind data sources were analyzed independently, giving deepwater wave conditions in lower Cook Inlet, Alaska, with probabilities from the Homer Airport wind distribution and from the Homer Spit wind distribution. Since the correlation between the two wind analyses was poor, the wave transformation analysis was continued in this parallel manner, treating the airport and the Spit distributions independently.

WAVE TRANSFORMATION MODEL

3. The Regional Coastal Processes wave model (RCPWAVE) (Ebersole, in preparation), was applied to Homer Spit to determine the wave climate resulting from the transformation of waves from lower Cook Inlet over the outer Kachemak Bay bathymetry. The model employs an iterative, finite difference scheme with full refraction and diffraction effects, assuming:

a. Small bottom slopes.

b. Waves are linear, monochromatic, and irrotational.

c. Wave reflection is negligible.

d. Energy losses due to bottom friction or wave breaking outside the surf zone are insignificant.

4. Application of the Wave Model: A stretched rectangular grid of 76 by 72 cells covering an area 22,500 ft by 60,000 ft was applied to Homer Spit with fine resolution in the nearshore region and coarse resolution offshore. Stretched grids minimize computer costs by minimizing the number of grid cells needed. The grid was oriented to minimize the number of land cells and to accomodate a maximum incident wave angle of 70 relative to the grid's x-direction. The x-direction is approximately perpendicular to the shoreline, and the y-direction is approximately parallel to the shoreline (Figure B-1). The grid's y-axis runs from Bluff Point, Alaska, southeastward to the tip of Homer Spit. The x-axis extends seaward to a depth of approximately 20 - 30 fathoms.

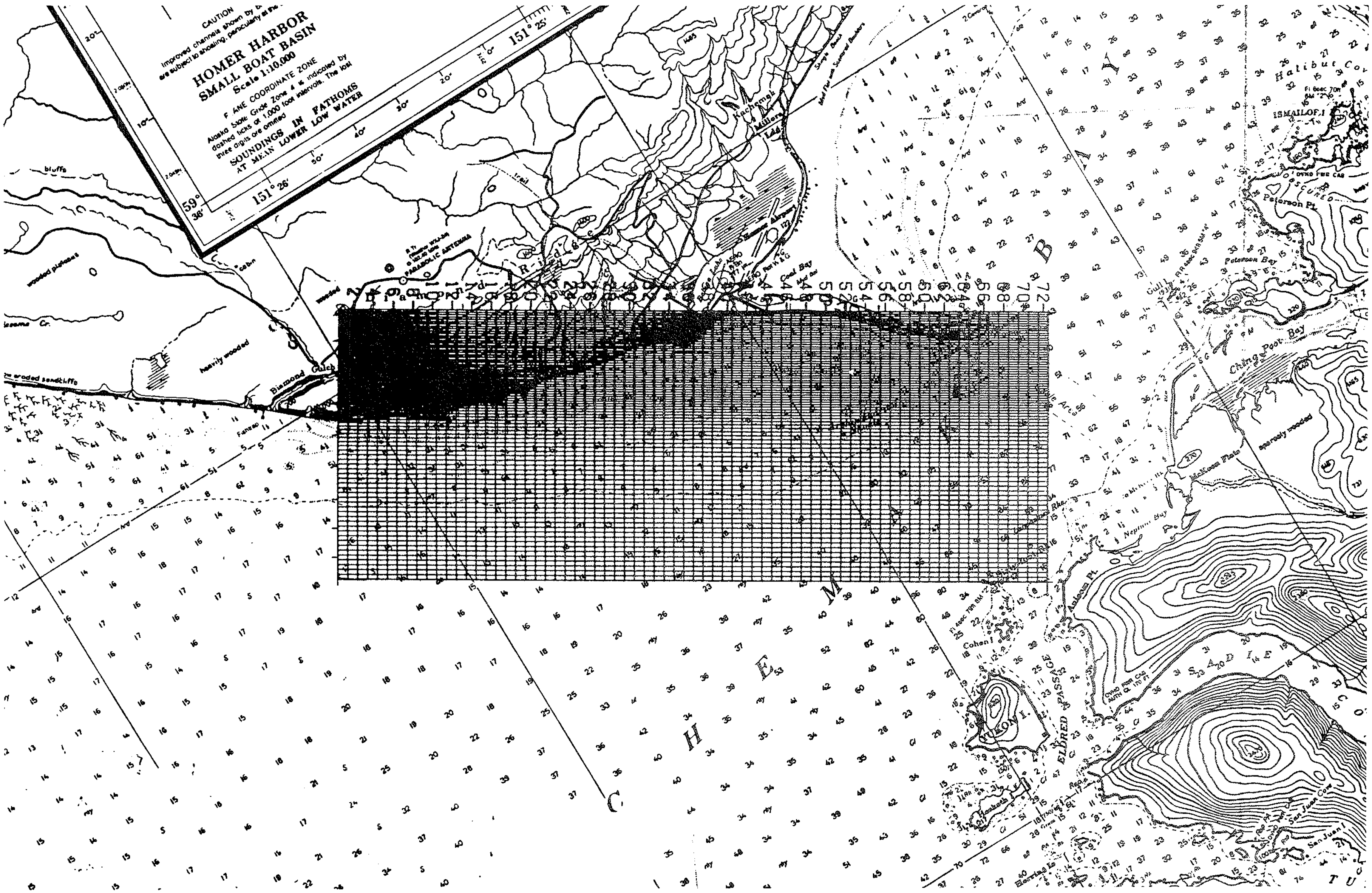

Figure B-1. Numerical grid applied in wave transformation analysis superimposed on Homer Spit, Alaska

5. The grid was overlayed on a National Ocean Survey (NOS) bathymetric chart to assign an average depth to each grid cell relative to MLLW. The lack of bathymetric data above MLLW precluded running the model with higher tidal elevations. The NOS bathymetric chart also lacked enough detail to resolve incipient breaking locations accurately. Therefore, a routine was developed to take the wave conditions one cell prior to breaking (SPM breaking criterion) and transform them to breaking conditions (breaking criterion of wave height = 0.78 * water depth) using Snell's law and the assumption of straight and parallel bottom contours. The wave conditions just prior to breaking include the wave height, wave period, and wave angle relative to the local shoreline. From the breaking conditions, the longshore energy flux factor (P_{ls}) was calculated using the following equation:

$$P_{ls} = \frac{1}{16} \rho g H_b^2 C_g \ (\sin 2\theta_b) \qquad \text{(SPM 1984)}$$

where:

ρ = mass density of water

g = acceleration of gravity

H_b = wave height at breaking

C_g = group velocity at breaking

θ_b = wave angle at breaking

6. The modified RCPWAVE model was used for the following tasks:

a. The model was run for each deepwater wave condition given in Table B-1 as previously calculated from the wind analysis. It should be noted that the wind analysis output wave height is energy-based significant height, and the period is the peak spectral period which the wave model treats as monochromatic. Figure B-2 is an example of wave transformation at Homer Spit, including refraction, diffraction, and shoaling. The arrow directions in Figure B-2 represent wave directions, and the arrow lengths represent the wave heights throughout the grid.

b. A P_{ls} value was calculated at each of the 72 shoreline grid cells for each deepwater wave condition.

c. Each P_{ls} value was weighted by the probability of occurrence associated with the deepwater wave condition. The probabilities for each wave condition can be obtained by subtracting successive cumulative probabilities of Table B-1. Each deepwater wave condition has two probabilities associated with it, one corresponding to the airport wind data (w(airport)) and one corresponding to the spit wind data (w(spit)). Therefore two weighted P_{ls} values were computed: (1) P_{ls} * w(airport) and (2) P_{ls} * w(spit), where w is the weighting factor.

TABLE B-1 - Deepwater Wave Statistics vs Cumulative Probabilities

WAVE HEIGHT (ft)	WAVE PERIOD (sec)	CUMULATIVE PROBABILITIES (occurrence per year) AIRPORT	SPIT
wave angle = -35.5 deg (relative to the grid x-direction)			
0.66	3.24	0.0772	0.0849
1.99	4.67	0.0767	0.0830
3.32	5.54	0.0630	0.0718
4.64	6.19	0.0427	0.0529
5.97	6.73	0.0215	0.0334
7.30	7.20	0.0074	0.0197
8.62	7.61	0.0021	0.0128
9.95	7.89	0.0004	0.0079
11.28	8.36	0.0001	0.0039
12.60	8.64	0.00002	0.0017
13.93	8.93	0.000004	0.0005
15.26	9.21	0.000004	0.00018
16.58	9.47	-	0.00009
17.91	9.71	-	0.00006
wave angle = -58.0 deg (relative to the grid x-direction)			
0.59	3.00	0.0375	0.0496
1.78	4.33	0.0361	0.0479
2.96	5.13	0.0228	0.0386
4.14	5.74	0.0127	0.0246
5.33	6.24	0.0061	0.0144
6.51	6.67	0.0021	0.0067
7.70	7.06	0.0006	0.0032
8.88	7.40	0.0001	0.0016
10.06	7.72	-	0.0007
11.25	8.01	-	0.0004
12.43	8.28	-	0.0002
13.62	8.53	-	0.00006
wave angle = -69.25 deg (relative to the grid x-direction)			
0.51	2.73	0.0133	0.0283
1.54	3.94	0.0129	0.0263
2.57	4.67	0.0052	0.0177
3.60	5.23	0.0020	0.0106
4.63	5.68	0.0007	0.0053
5.66	6.08	0.0001	0.0027
6.69	6.42	0.00005	0.0011
7.71	6.74	0.000004	0.0004
8.74	7.03	-	0.0001
9.77	7.29	-	0.00006
10.80	7.54	-	0.00003

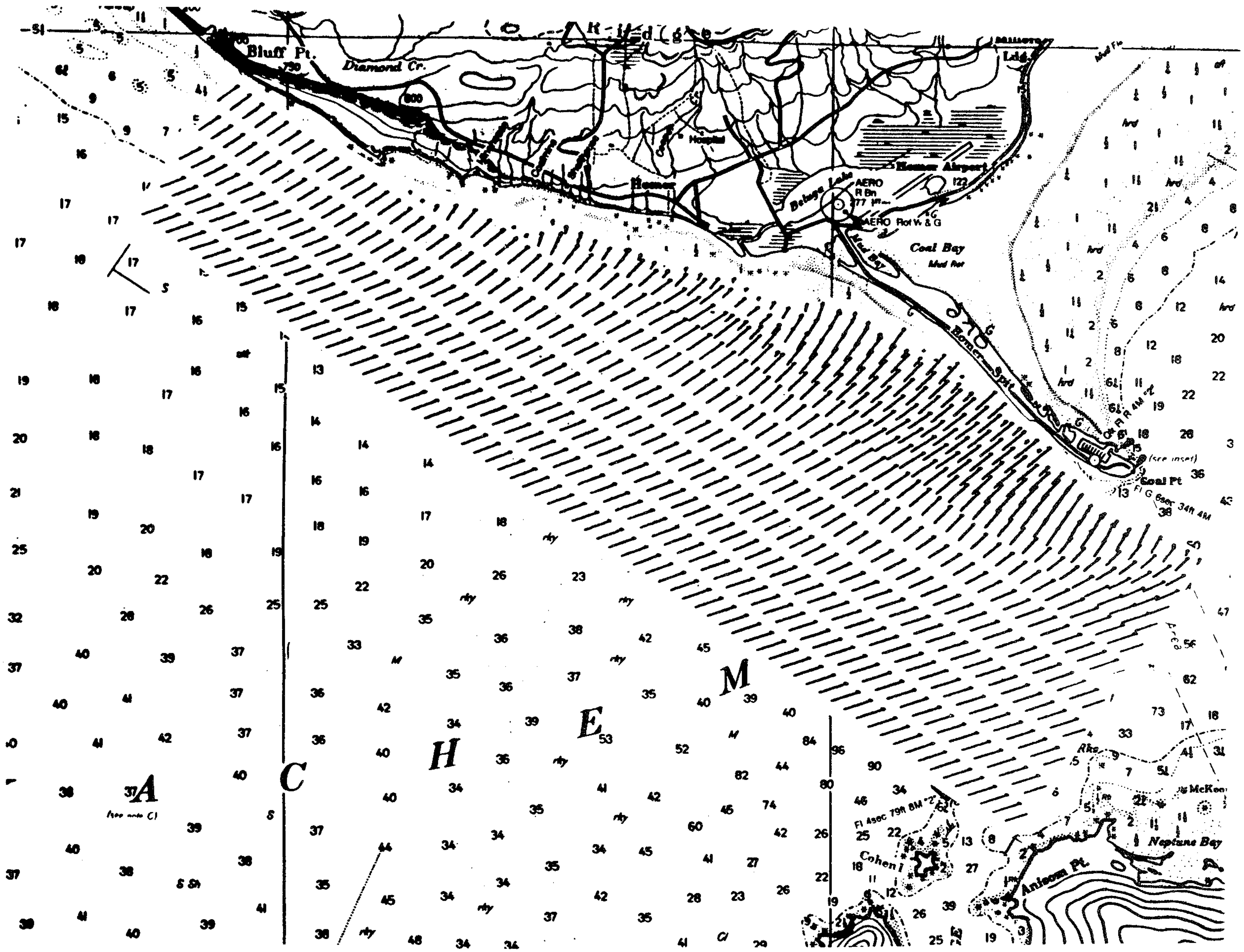

Figure B-2 - Sample wave transformation

d. At each grid cell the P_{ls} values for all wave conditions run were summed as follows:

$$\overline{P}_{ls}(\text{airport})j = \sum_{i=1}^{n} (P_{ls})_{ji} * w(\text{airport})_i \qquad \text{and}$$

$$\overline{P}_{ls}(\text{spit})j = \sum_{i=1}^{n} (P_{ls})_{ji} * w(\text{spit})_i$$

where:

n = number of wave conditions

$(P_{ls})j_i$ = the longshore energy flux factor at shoreline cell (j) for wave condition (i)

$(\overline{P}_{ls})_j$ = the expected annual P_{ls} for j

w = weighting factor for i

This resulted in an expected annual average P_{ls} value for each shoreline cell for the airport wind distribution and for the Spit wind distribution (Table B-2 and Figures B-3 and B-4).

SEDIMENT TRANSPORT ESTIMATE

7. Longshore sediment transport rate (Q) was estimated directly from P_{ls} using Equation 4-49 in the SPM (1984) as follows:

$$Q = K(P_{ls})/ga'(\rho_s - \rho_w)$$

where:

$K = 0.265 \log (gH/V_f^2) - 0.53$ (from unpublished CERC research findings)

V_f = fall velocity of sediment

g = acceleration of gravity

a′ = volume solids/total volume (accounts for sediment porosity)

ρ_s = mass density of sediment

ρ_w = mass density of water

A K value of 0.52 was computed for the 0.3-mm-diameter sediment typical of the low tide regions of the Spit, as above, assuming a conservative 5-ft significant wave height. It was also assumed that longshore transport at high

TABLE B-2. Expected Annual $\overline{P}_{1s}$

CELL	$\overline{P}_{1s}$ AIRPORT	$\overline{P}_{1s}$ SPIT	CELL	$\overline{P}_{1s}$ AIRPORT	$\overline{P}_{1s}$ SPIT
10	54.1	111.1	37	73.4	146.9
11	63.2	124.1	38	75.7	143.2
12	86.4	176.8	39	96.4	186.5
13	83.3	171.7	40	81.9	143.4
14	71.0	144.3	41	9.8	55.4
15	67.5	137.2	42	-8.6	-4.2
16	62.3	128.4	43	-21.4	-32.9
17	81.1	168.8	44	-0.9	5.5
18	26.3	71.0	45	4.3	11.5
19	72.1	152.0	46	0.8	8.3
20	69.6	148.9	47	8.1	16.9
21	74.3	159.2	48	8.2	18.4
22	60.7	133.6	49	13.0	27.2
23	46.0	104.4	50	15.7	31.0
24	-10.7	20.8	51	21.2	47.3
25	2.6	8.6	52	13.0	24.5
26	19.2	44.9	53	2.0	3.0
27	37.0	78.4	54	13.7	19.3
28	48.4	100.0	55	15.2	20.9
29	48.5	105.8	56	22.8	30.3
30	47.9	97.0	57	23.6	33.0
31	49.5	109.3	58	46.8	75.8
32	50.8	111.2	59	39.4	61.6
33	21.8	61.4	60	49.4	75.9
34	4.2	32.5	61	58.1	90.6
35	-5.4	12.1	62	45.6	65.6
36	40.3	110.8	63	40.2	57.8

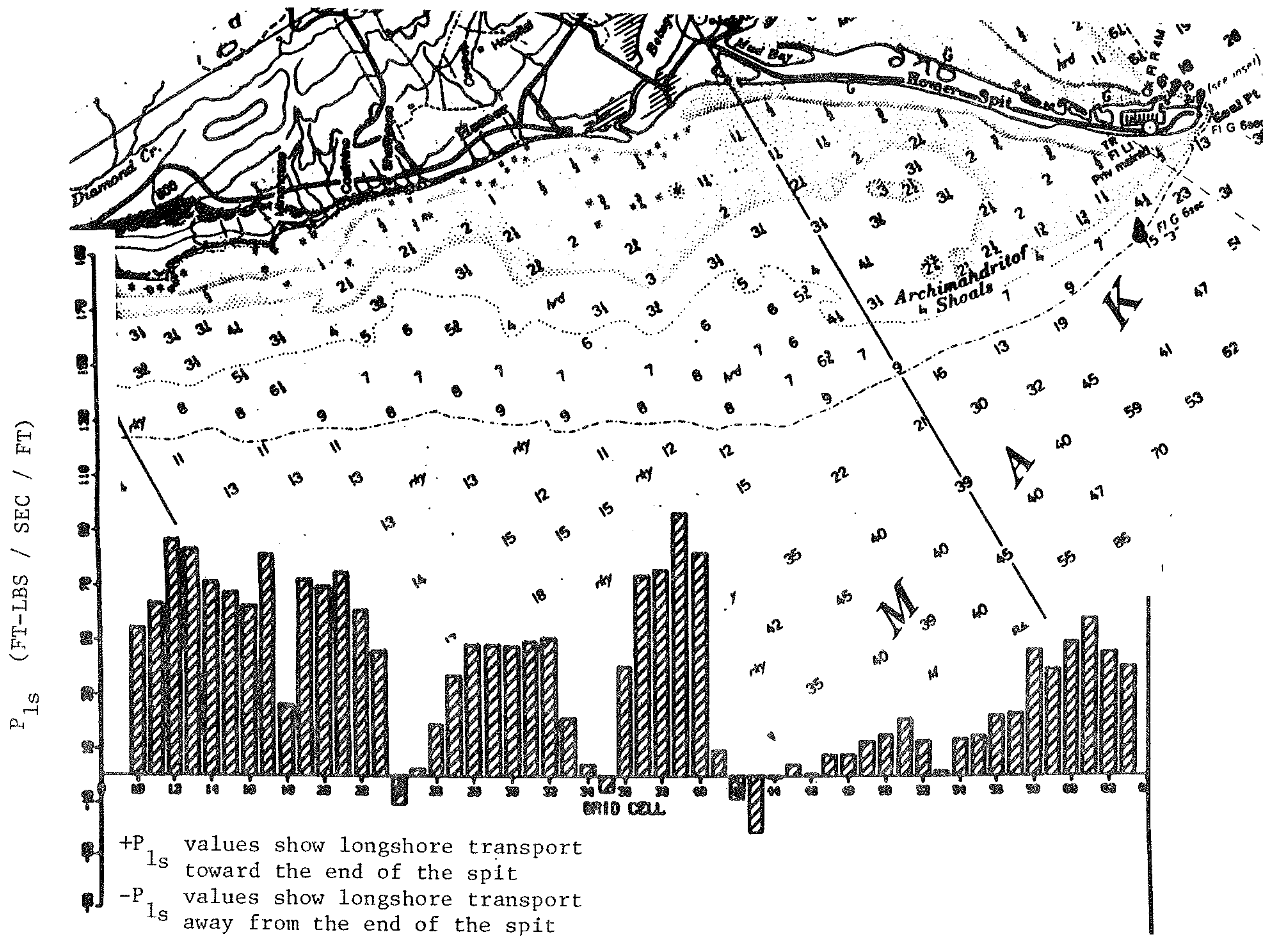

Figure B-3. Expected annual $\bar{P}_{1s}$ for each grid cell (airport wind distribution)

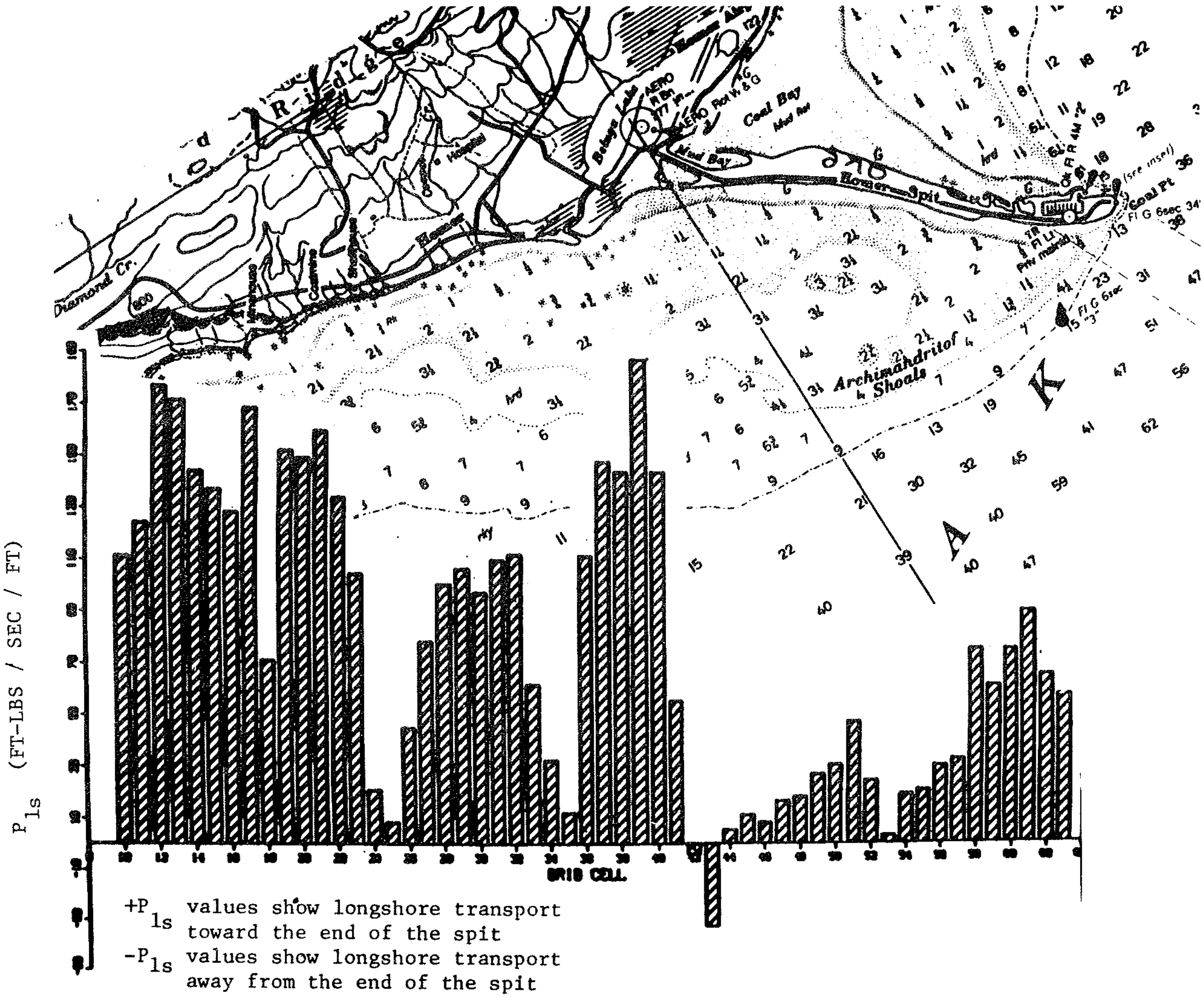

Figure B-4 - Expected annual $\overline{P}_{1s}$ for each grid cell
(spit wind distribution)

tide is negligible due to the large sediment sizes typical on this part of the beach profiles (gravel and cobbles). An additional simplifying assumption of a step function tidal variation (versus the natural sinusoidal variation) allowed an overall average K value of 0.26 to be estimated. This resulted in estimates of annual longshore transport (in cu yds/yr) equal to 5,000 P_{1s}. The SPM recommends using a larger constant in this expression, 7,500 (cu yds/lb-yr) instead of 5,000 (cu yds/lb-yr), for beaches with medium to fine sand; but this is meant as a first approximation based on more uniform conditions with much smaller tidal variation. Figure B-5 shows the distribution of sediment transport rate along the spit based on the airport distribution and the K value of 0.26. Figure 9 in the main report shows the equivalent rate distribution based on the spit wind distribution. Figures B-6 and B-7 show changes in the sediment transport rate (dQ) along the shoreline (S) or dQ/dS. A positive value of dQ/dS indicates an increasing transport rate toward the end of the spit, an indication of erosion. A negative value of

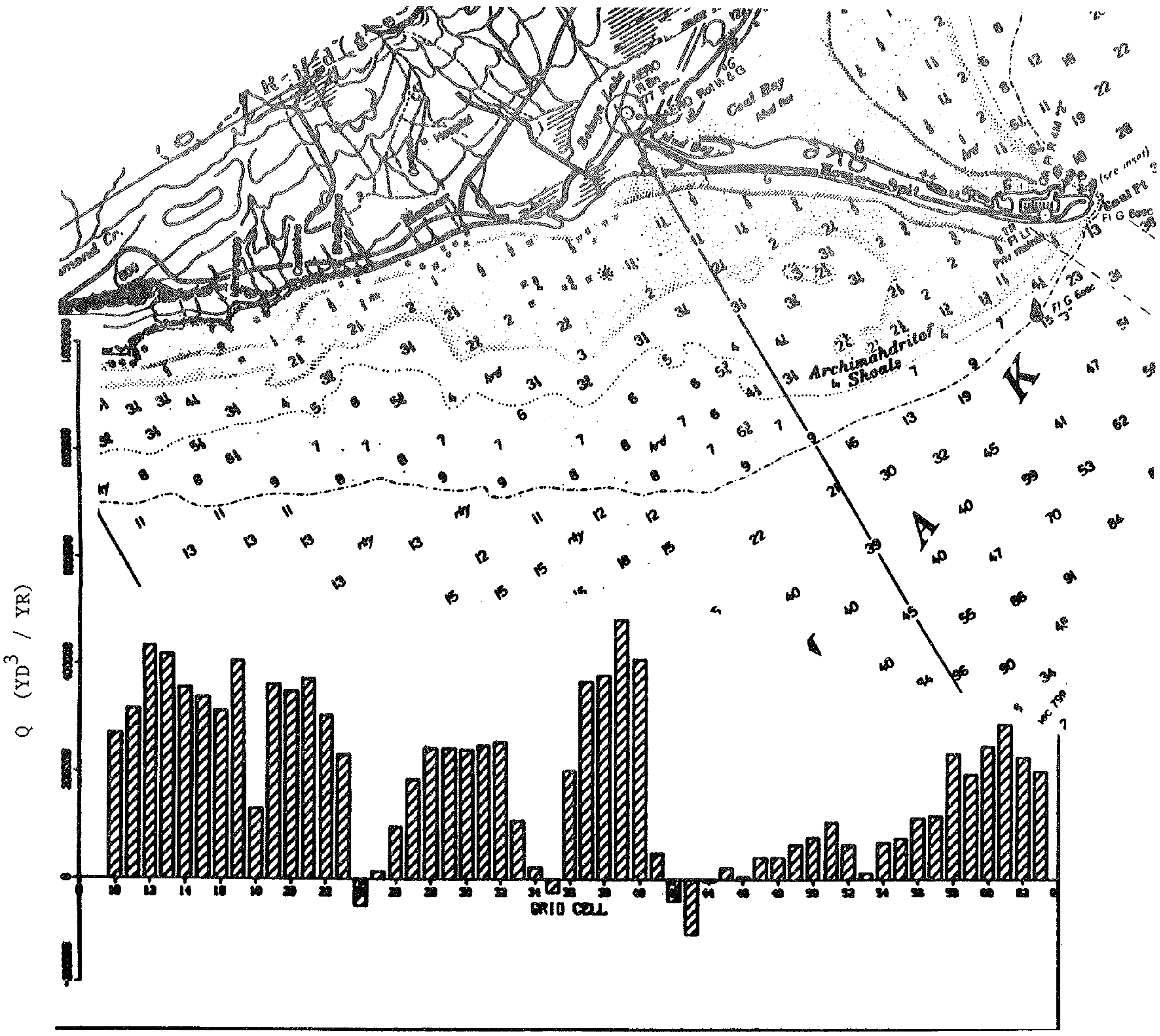

Figure B-5 - Expected annual sediment transport for each grid cell (airport wind distribution)

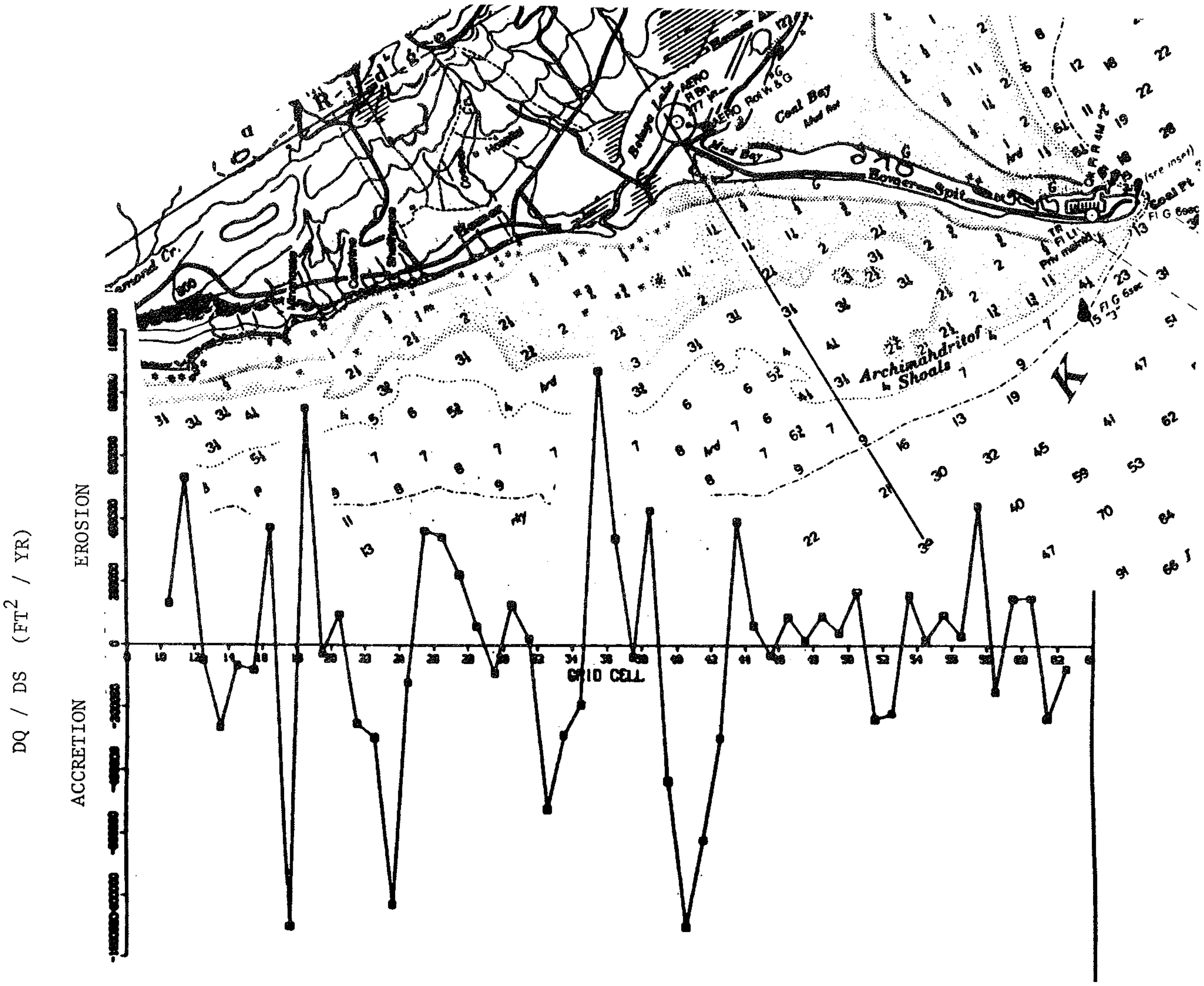

Figure B-6 - Change in sediment transport rate per increment of shoreline (spit wind distribution)

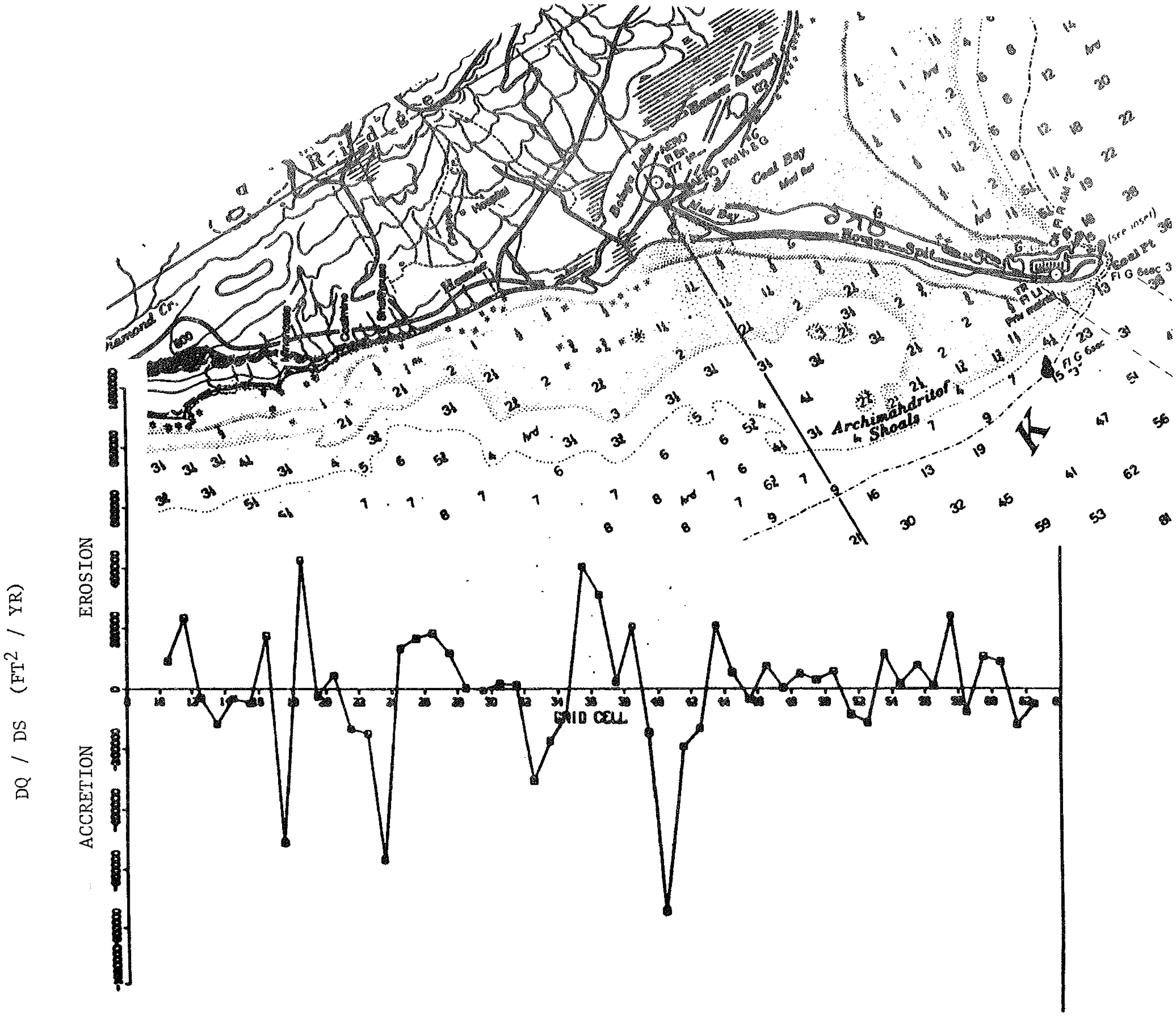

Figure B-7 - Change in sediment transport rate per increment of shoreline (airport wind distribution) dQ/dS indicates an area of local accretion. The erratic variation of dQ/dS illustrates the need for more accurate hydrographic data in the wave model and additional wind and wave data for improved confidence. Visual smoothing reveals a rough correspondence between major variations and the known areas of erosion, however.

SUMMARY

8. Deepwater wave conditions were numerically transformed to breaking conditions using the RCPWAVE model. The breaking conditions were used to estimate the expected annual longshore energy flux factor (P_{ls}) at each shoreline grid cell. P_{ls} is directly related to the sediment transport rate and direction (Q). Figure B-5 and Figure 9 in the main report show trends in sediment transport such as convergence and divergence. The predominant predicted sediment transport direction is toward the end of the spit (Southeast), but localized reversals in the longshore transport and related sediment deficits are predicted in the vicinity of the base of the spit.

APPENDIX C: Coastal Geology

GEOLOGICAL HISTORY

1. Introduction: An understanding of the origin and historical development of Homer Spit is necessary in order to understand the processes currently at work and to predict the future condition. The following discussion concerning the geological history of the region and speculation on the evolution of Homer Spit is presented in hopes of providing a better understanding of the observed conditions. The discussion is hypothetical and, although it is consistent with the observations of most previous investigators, it has not been rigorously tested with field measurements.

2. Glacial History: The observed sediment transport patterns at Homer Spit are the result of a modern wave climate acting on the glacial and post-glacial deposits of the area. Glacial deposits, some reworked during interglacial periods by fluvial processes, serve as the source for the littoral sediments. The glaciation history of Cook Inlet is one of the most complex and controversial issues in Alaskan geology. Cook Inlet has experienced at least five Pleistocene ice advances separated by fairly short intervals of soil formation and weathering. Final deglaciation of the Cook Inlet area began about 13,500 years ago and continued for several thousand years (Hamilton and Thorson, 1983). The Homer area was near the boundary between a proglacial lake or marine embayment and an unglaciated area within the ice sheet. Kachemak Bay was glaciated at this time. The closest radioactive carbon dates are 9,000 to 10,000 years ago for a basal peat deposit at Ninilchik of the same stratigraphic unit that is exposed at Anchor Pt (Hamilton and Thorson, 1983). Even after glaciation, this area remained depressed below sea level for some time and was isolated from the Gulf of Alaska by a remnant glacier which blocked the mouth of Cook Inlet at Kodiak.

3. Age and Origin of the Spit: Borings taken near the terminus of Homer Spit contain shells, sand, and gravel suggesting that the full thickness of the terminus of Homer Spit is littorally derived. No subsurface information existed at the time of this investigation elsewhere along the Spit; consequently there is no firm proof whether the whole of Homer Spit is littorally derived or if the basement may be founded upon a relict glacial moraine. Given the glacial and postglacial history of this area, it is reasonable to hypothesize that Homer Spit is generally younger then 7,000-8,000 years and that it formed both horizontally and vertically due to littoral processes. One radiocarbon dating analysis was conducted of a buried soil profile in an interior beach ridge of Homer spit during this study. That sample was taken from approximately 5 ft down and indicates the age of middle portion of the present surface of Homer Spit as being approximately 800 yrs old.

FIELD DATA AND ANALYSES

4. Visual Observations: An extensive set of observations was made by CERC specialists during a field investigation at Homer Spit in August 1984, including visual inspection of beach form and sediment characteristics at each of 67

beach profile locations, as shown in Figure 6 of the main report. A summary of these visual observations related to the coastal geology of the Spit are included as Supplement 1 to this Appendix.

5. Sediment Sampling and Testing: Ninety-nine sediment samples were collected from the beach face, relict beach ridges, source area bluffs, updrift beaches, and offshore of Homer Spit during the August 1984 field trip. The samples were obtained on a number of the established profile stations at the high tide storm berm, on the upper foreshore slope, the mid-foreshore slope, the lower-foreshore slope, and on the low tide terrace with a backhoe provided by the City of Homer or with a handheld shovel . The use of a backhoe and the acquisiton of large samples were necessary to accurately represent the fractions of large cobble and gravel-sized beach material. Offshore samples were obtained on select profiles with a small Petersen grab sampler. A gradation analysis of each sample was subsequently conducted by NPA. The results of the gradation analyses were statistically analyzed with results as summarized in Table C-1.

6. Cluster Analysis: The statistical technique of cluster analysis was applied to 73 of the August 1984 Homer sediment samples. A set of five characteristic gradation curves was derived for these samples, as illustrated in Figure C-1. The spatial distribution of each cluster is illustrated in Figures C-2 and C-3. Cluster 1 is a medium to fine-grained sand which dominates the low tide terrace and the updrift beaches. Cluster 4 is a very fine-grained silty sand which typically occurs on the offshore extension of the low tide terrace. The occurrence of cluster 4 may indicate the offshore limit of active sediment transport around Homer Spit. Cluster 5 applied to only 2 samples, but it apparently illustrates the clayey silt which is found offshore of the littorally active zone of Homer Spit. Clusters 2 and 3 are poorly sorted sands with gravel and cobbles which make up the upper foreshore of Homer Spit. Cluster 2 is slightly more coarse then Cluster 3 and is found in the higher energy sections of Homer Spit. Figure C-2 shows that Cluster 2 tends to dominate the upper foreshore slopes and high-water storm berms, particularly around the head, which are exposed to higher wave energy. The results of the cluster analysis appear to be consistent with the relative distribution of wave energy around Homer Spit and the offshore limits of the low tide terrace. Potential sources of beach fill-material can be evaluated in terms of their similarity to these natural gradations along the Spit.

CONCLUSIONS

7. Morphological Regimes: Homer Spit can be perceived to include three different morphological regimes. These regimes appear to have significantly different development histories, present morphology, beach widths, offshore characteristics, and coastal processes. Figure C-4 is an August 1952 aerial photograph of Homer Spit taken before the 1964 earthquake and before subsequent construction activities substantially modified the geomorpholgy of the Spit. Three distinctive sequences of beach ridge evolution are visible in Figure C-4. These areas suggest eposodic growth of Homer Spit consistent with the wave energy distribution pattern estimated as a part of this study (Appendixes A and B). These relict morphological beach ridge zones also parallel the observed modern beach morphology.

Table C-1 - Results of Gradation Analysis for Samples Collected Along Homer Spit, Alaska

HOMER SPIT, ALASKA: SPIT EROSION STUDY

SEDIMENT SAMPLES COLLECTED AUGUST 1984

SAMPLE	MEAN SIZE	STD DEV	SKEWNESS	KURTOSIS	PERCENT GRAVEL	PERCENT COARSE SAND	PERCENT MEDIUM SAND	PERCENT FINE SAND	PERCENT SILT CLAY
HOMER BLUFF #1	1.26	3.33	-1.37	10.94	18.40	1.10	9.00	71.50	.00
HOMER BLUFF #2	2.05	2.05	-2.22	16.63	5.90	1.10	13.60	79.40	.00
BLUFF PT FS@HT	.94	.58	-6.17	33.03	.90	1.00	90.20	8.80	.00
BLUFF PT FS@LT	.95	1.01	-1.85	7.82	2.20	2.70	51.70	43.40	.00
HOMER BLUFF #5	2.38	.76	-.41	2.82	.00	.00	5.90	94.10	.00
HOMER BLUFF #6	-2.11	2.59	.02	4.87	50.90	8.50	30.70	9.90	.00
HOMER BLUFF #7	1.02	.83	-2.41	13.96	1.30	1.20	71.20	26.30	.00
ELKS CLUB TF-SF	1.46	.67	.00	4.91	1.00	.30	30.90	68.70	.00
ELKS CLUB TF#1	1.32	.52	-1.69	6.83	1.00	.40	36.70	62.80	.00
ELKS CLUB TF#2	1.59	.65	1.01	3.26	.00	.00	25.30	74.70	.00
HOMER AIRPORT	.39	2.27	-.57	5.60	16.30	6.10	39.10	38.50	.00
BELUGA LAKE BL	-.48	3.79	-.35	5.80	37.80	4.20	11.70	46.30	.00
BP 1-1 FS@HT	-3.95	.59	3.16	19.99	98.70	.80	.40	.10	.00
BP 1 FS@MT	-2.59	2.33	.35	4.08	59.50	7.60	28.20	4.70	.00
BP#2 HT BERM	-3.24	1.87	1.30	9.05	68.60	19.60	8.90	2.90	.00
BP 2-1 @LOW TD	-.59	2.36	-.67	4.44	29.30	5.00	40.20	25.50	.00
BP#4 FS@HT	-3.20	2.64	.64	5.70	67.90	3.40	15.90	7.60	.00
BP#4 FS@LT#1	-2.83	3.10	.05	5.36	57.00	8.50	21.10	13.40	.00
BP#4 FS@LT#2	-2.39	3.16	-.16	5.53	49.80	8.50	26.10	15.60	.00
BP#4 FS@LT#3	-2.43	2.85	.14	4.85	54.00	8.20	24.20	13.60	.00
BP#6 FS@HT	-3.22	2.79	.55	5.31	68.40	3.50	22.30	5.80	.00
BP#6 FS@LT	-3.21	2.83	.34	5.49	65.00	8.10	17.60	9.30	.00
BP#8 FS@HT	-3.37	2.59	.60	5.61	70.50	5.70	18.50	5.30	.00
BP#8 FS@LT	-2.63	2.81	.25	4.87	60.60	6.20	20.70	12.50	.00
BP#8 125 OFFSH	-3.25	1.72	2.04	12.55	84.00	7.60	2.20	6.20	.00
BP#10 FS@HT	-3.22	2.75	.45	5.18	67.30	4.40	22.60	5.70	.00
BP#10 FS@LT	-2.44	2.57	.22	5.04	58.70	10.10	19.10	12.10	.00
BP#13 FS@HT	-3.40	2.91	.40	6.16	67.20	7.30	18.80	6.70	.00
BP#13A FS@LT	-1.86	2.44	.11	4.60	50.50	12.00	21.50	16.00	.00
BP#15-2 FS@HT	-3.57	2.58	.60	5.85	71.60	7.10	16.80	4.50	.00
BP#15 FS@LT3'D	-.84	2.38	-.36	4.10	33.10	11.30	24.30	31.30	.00
BP#15 LTT SURF	.39	1.62	-1.45	6.43	11.10	6.60	48.40	33.90	.00
BP#15 LTT 3FT D	-1.41	2.85	-.33	4.73	40.40	9.40	21.10	29.10	.00
BP#17 FS@HT	-3.90	2.85	.40	5.84	71.90	7.20	17.50	3.40	.00
BP#17 FS@LT	-3.84	2.85	.45	5.91	71.90	7.40	15.80	4.90	.00
BP#17 LTT UP3'	.68	2.19	-.67	5.90	13.80	6.90	32.80	46.50	.00
BP#17 LTT-3.0	-.76	2.55	-.77	6.26	29.60	9.50	29.90	31.00	.00
BP#22 FS@HT	-3.75	2.75	.53	5.54	71.10	6.20	19.40	3.30	.00
BP#22 FS@LT	-5.00	2.98	.79	7.49	81.00	6.10	8.80	4.10	.00
BP#22 LTT@SURF	1.26	.82	-3.15	14.45	1.50	1.10	33.70	63.70	.00
BP#22 LTT@-3.0	-2.89	4.00	.00	4.74	52.30	2.30	20.90	24.50	.00

(Continued)

Table C-1 - (Concluded)

SAMPLE	MEAN SIZE	STD DEV	SKEWNESS	KURTOSIS	PERCENT GRAVEL	PERCENT COARSE SAND	PERCENT MEDIUM SAND	PERCENT FINE SAND	PERCENT SILT CLAY
BP#22 1500 OFF	2.63	.45	-1.14	5.64	.00	.00	.70	99.30	.00
BP#22 2000 OFF	2.44	.78	-.44	2.37	.00	1.00	4.30	95.60	.00
BP#22 2250 OFF	1.10	2.22	-1.99	13.23	11.00	.90	9.60	78.50	.00
BP#22 2500 OFF	2.33	1.04	-1.10	5.46	.30	.60	10.20	88.90	.00
BP#27 FS@HT	-2.45	2.18	-1.98	9.01	46.00	.60	.10	.00	4.80
BP#27 MIDTIDE	-3.78	2.53	.60	6.15	70.80	13.40	11.40	4.40	.00
BP#27 LTT@SURF	1.20	.82	-2.64	10.80	1.10	1.70	38.10	59.10	.00
BP#36A TOPOBCH	-4.13	2.88	.48	5.60	71.90	6.20	20.00	1.90	.00
BP#36A HIGH TD	-3.55	2.86	.27	5.52	67.60	6.80	21.70	3.90	.00
BP#36A MIDTIDE	-4.66	2.98	.65	6.61	77.20	6.10	13.30	3.40	.00
BP#36A LTT@LT	.15	2.16	-1.71	10.15	13.60	3.30	46.80	36.30	.00
BP#36A 1750 OF	2.53	.48	-3.23	16.09	1.00	1.00	1.00	98.80	.00
BP#36 2000 OFF	-5.32	.68	6.21	40.16	99.20	.40	.20	.20	.00
BP#39 FS@MT	-2.96	2.71	.36	5.23	62.90	8.20	23.20	5.70	.00
BP#39 LTT	1.10	.88	-3.23	14.99	1.90	1.40	46.30	50.40	.00
BP#39 LTT@LT	.67	1.47	-2.07	10.23	7.50	3.30	54.20	35.00	.00
BP#42 LTT@LT	1.77	.78	-1.38	7.15	.20	.70	10.30	88.80	.00
BP#42 1500 OFF	2.23	1.09	-4.35	27.90	2.00	.50	2.00	95.50	.00
BP#44 FS@HT#1	-1.53	2.48	-.35	4.34	39.60	8.00	44.00	8.40	.00
BP#44 FS@HT	-2.39	2.72	.06	4.75	54.90	7.60	27.00	10.50	.00
BP#44 FS@LT	-3.66	2.99	.38	6.31	69.70	5.90	16.40	8.00	.00
BP#44 LTT@LT	1.38	1.33	-2.35	13.18	3.20	2.30	17.70	76.80	.00
BP#44 2000 OFF	2.67	.61	-3.07	14.61	.20	.10	2.30	97.40	.00
BP#44-6 2500 O	-6.28	.79	9.02	73.52	99.00	.10	.40	.50	.00
BP#45 1500 OFF	2.64	.47	-.73	3.89	.00	.00	1.00	99.00	.00
BP#49 FS@MT	-3.08	2.74	.57	5.39	67.20	6.10	15.20	11.50	.00
BCH RDGE,200E52	-.08	2.48	-.73	6.41	21.30	3.10	51.30	24.30	.00
BP#54 1500 OFF	2.67	.46	-1.29	5.51	.00	.00	1.10	98.90	.00
BP#54 2000 OFF	2.50	.75	-1.08	3.60	.00	1.00	5.80	94.10	.00
BP#54 2500 OFF	-5.88	.21	1.38	.70	*****	.00	.00	.00	.00
BP#54 3000 OFF	-5.94	.76	2.83	15.97	99.80	.00	.10	.10	.00
BP#54 6000 OFF	-6.41	.22	5.00	13.58	*****	.00	.00	.00	.00
BP#57 LTT	.24	2.42	-1.57	9.49	17.50	2.70	24.40	55.40	.00
BP#60 FS@MT	-3.00	2.44	.46	4.79	64.50	8.30	23.40	3.80	.00
BP#60 LTT	1.39	.60	-1.78	8.36	.20	.60	28.20	71.00	.00
BP#60 LTT UP3'	.67	2.07	-2.41	15.08	10.30	.80	26.30	62.60	.00
BP#60 LTT 3'DN	-2.80	2.61	.48	5.44	66.00	5.20	17.30	11.50	.00
BP#60 LOWERLTT	3.07	1.17	-3.47	18.17	1.70	.80	4.00	93.50	.00
BP#60 2000 OFF	.64	1.03	2.17	5.07	.00	.00	.80	23.20	.00
BP#60 3000 OFF	-6.50	.02	22.29	11.12	*****	.00	.00	.00	.00
NEW HBR CONST	-2.86	2.87	.35	5.01	60.60	5.90	24.90	8.60	.00
OLD HBR EXCAV	-2.31	2.73	.29	4.35	56.50	5.80	25.10	12.60	.00
ENTR CH DREDGE	.42	1.80	-2.36	13.69	9.50	1.30	69.30	19.90	.00
CHANNEL MKR#3	2.90	.95	-2.00	7.29	1.00	.50	6.60	92.80	.00

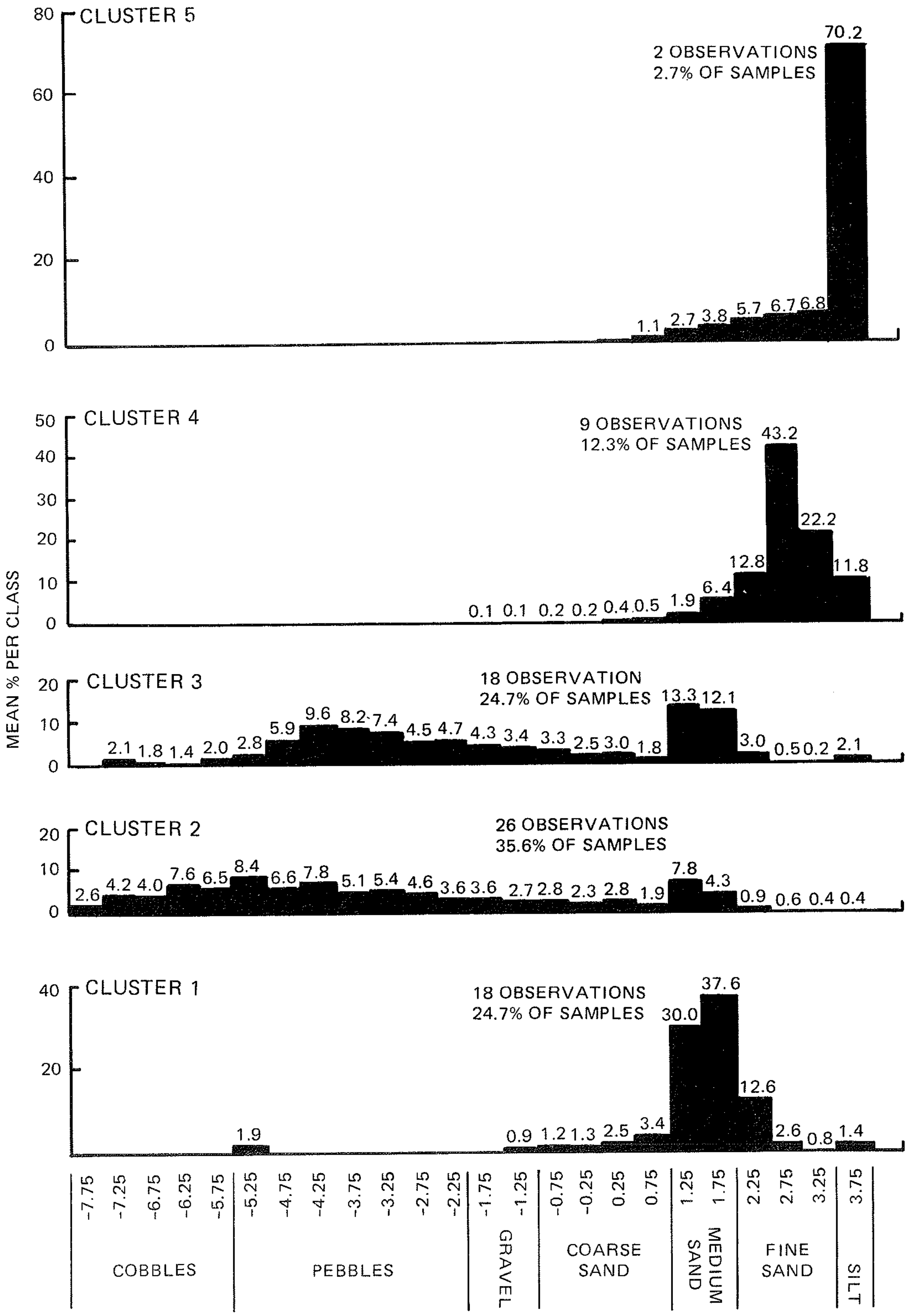

Figure C-1. Results of cluster analysis for sediment samples collected along Homer Spit, Alaska, August 1984

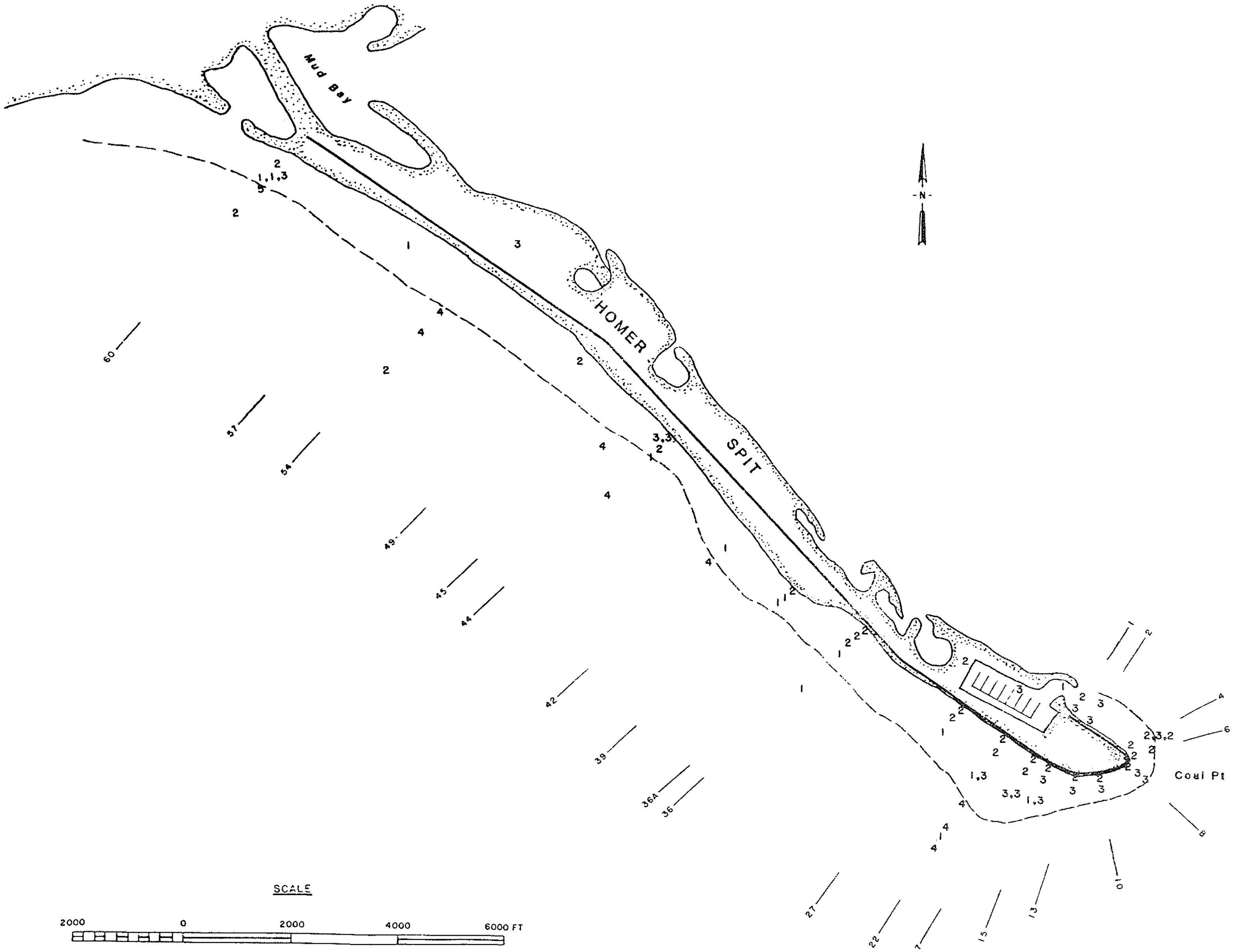

Figure C-2. Distribution of sediment cluster types along Homer Spit, Alaska

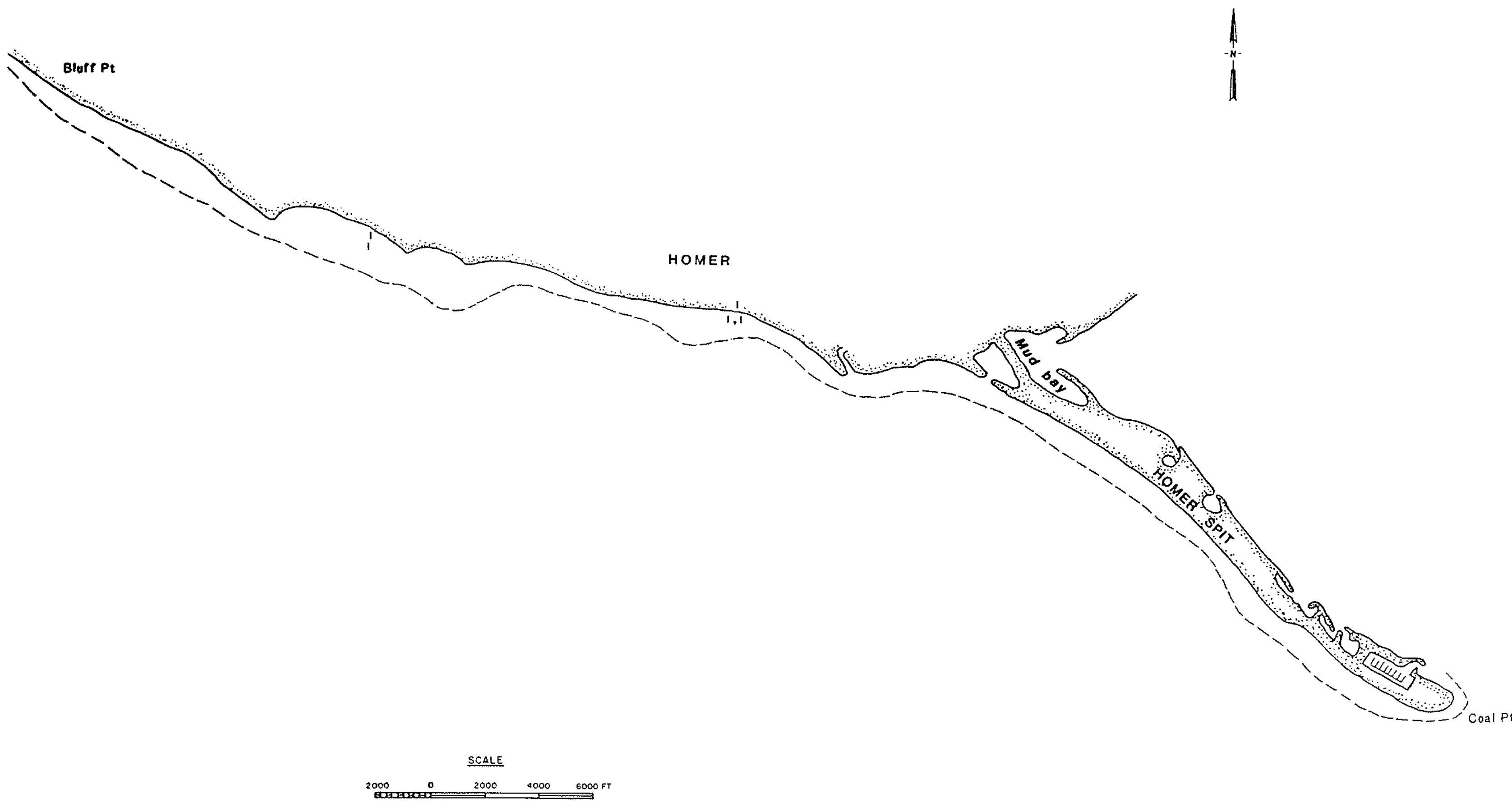

Figure C-3. Distribution of sediment cluster types along Homer Spit, Alaska

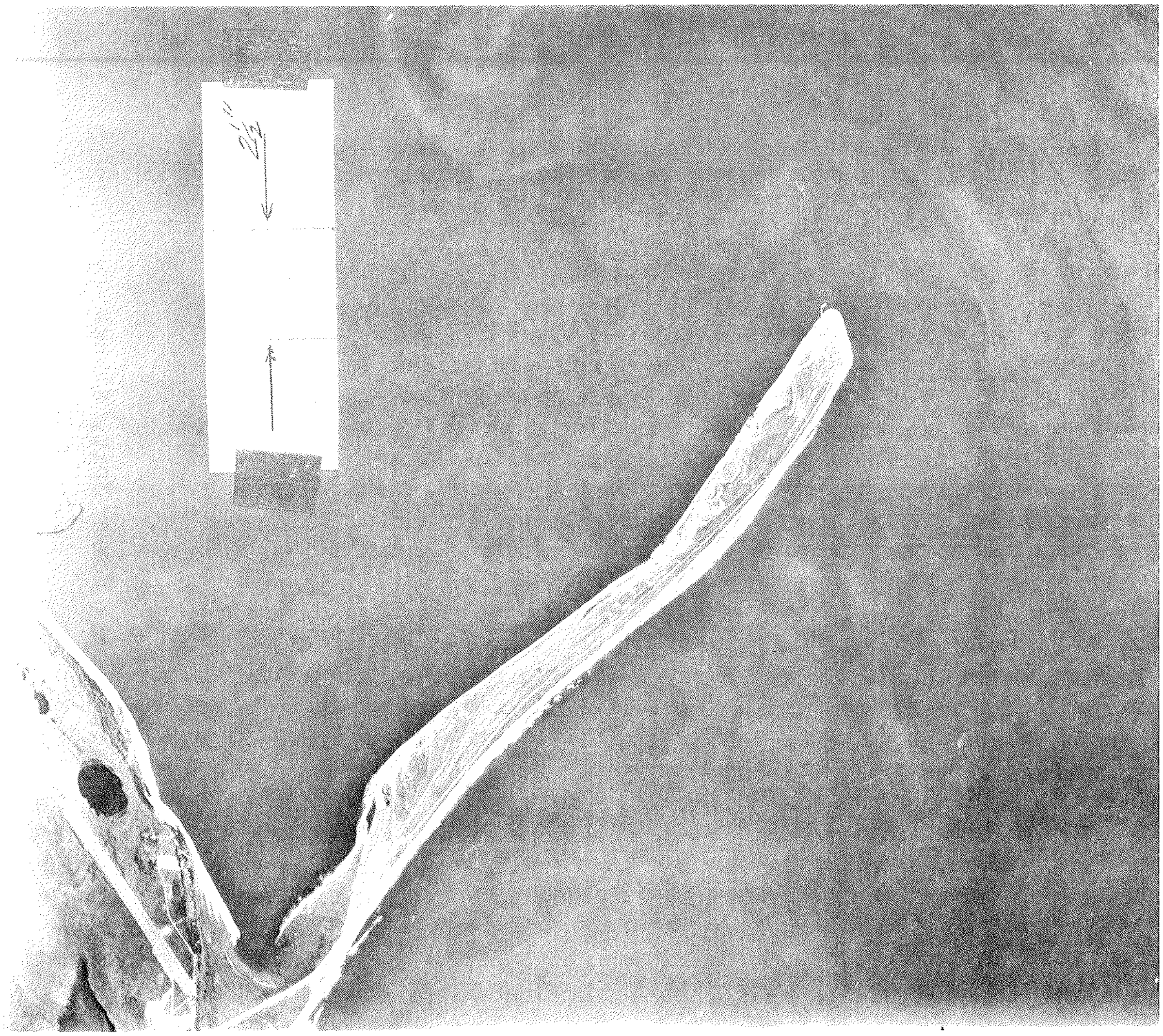

Figure C-4. Aerial Photo of Homer Spit, Alaska, 15 August 1952

8. The outermost and presumably youngest regime of the Spit extends from the harbor entrance around the tip approximately to profiles 36-38. This area is characterized by high wave energy, strong tidal currents, steep profiles, very deep water immediately offshore of the tip itself, and an ebb-tidal delta on the Inlet side (i.e. the Archimandritof Shoals). The morphology prior to recent sediment reworking activities was characterized by beach ridges recurved toward the Bay side by wave action. The foreshore beach material is coarser than other areas of the spit. This area was greatly affected by the 1964 earthquake which caused underwater slope failures on both sides of the tip and nearly 7-ft elevation loss from soil compaction and tectonic subsidence (Stanley, 1971). The head is currently the most heavily developed portion of the spit. It has apparently been quite stable throughout documented history, aside from the immediate effects of the 1964 earthquake, and it currently shows no outward evidence of recession or accretion trends.

9. The transition regime or the "body" of the Spit is the area from profiles 38 to 53-55. The body of the Spit is made up of relatively long beach ridges, slightly concave toward the Inlet. The low tide terrace is lower and more narrow in this area than on either side at its boundaries. Thus it provides less protection from wave action to the spit proper. The slight concavity of

the beach ridges points to the possibility that the area is a littoral divergence zone where material is being lost. This hypothesis is consistent with the long-term historical experience with highway maintenance problems in the vicinity of profiles 46 to 49. The middle regime was probably formed during a long period of relatively mild wave conditions when heavier sediment concentrations were present in lower Cook Inlet.

10. The base regime or landward connection extends from approximately profile 55 to the base of the spit and includes most of the existing revetment which protects the highway. The Spit is again made up of recurved beach ridges in this area. The low tide terrace is wide and pronounced. This area appears to be an accretionary region of the spit, partially protected from the north by the deltaic feature offshore of Beluga Lake which includes a nearshore boulder field that is exposed at low tide (as shown in Figure C-5). Although this feature may function in part as an updrift groin that partially blocks littoral transport, it probably also attenuates some wave energy from the northwest. This sheltering effect causes the base regime to accrete material and further disrupt the sediment supply to the central body of the Spit, which is not protected from the sediment transport capacity of waves off Cook Inlet. Since the base regime is accretionary, the disruption of sediment supply to the body of the Spit is gradually growing worse.

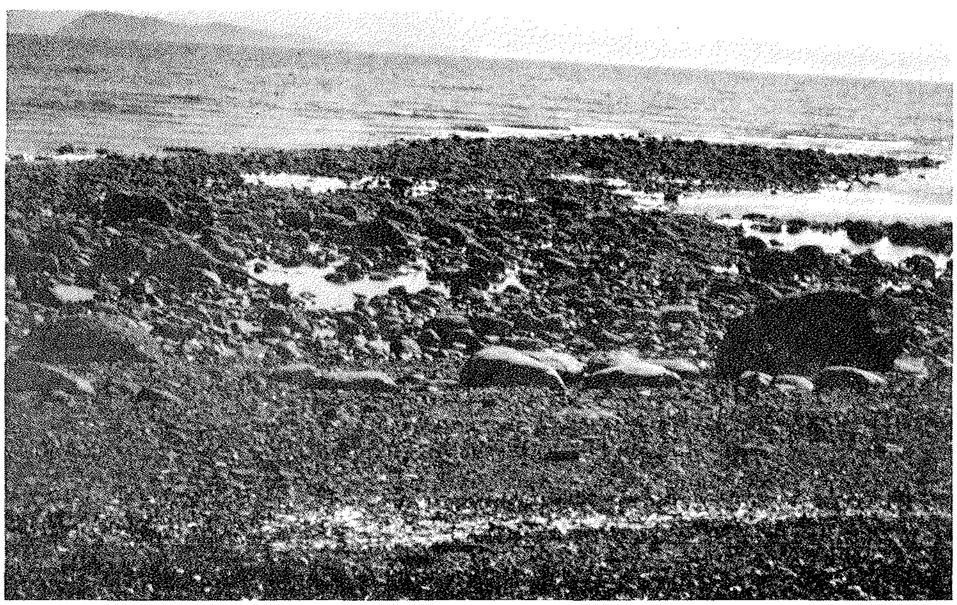

Figure C-5. Boulder Field at low tide off Beluga Lake, Homer, Alaska, August 1984

APPENDIX C: Supplement 1

VISUAL OBSERVATION OF BEACH MORPHOLOGY AT HOMER SPIT

AUGUST 1984

The following descriptions of beach characteristics were developed during a walking inspection of Homer Spit from 8 to 12 August 1984. The positions are in reference to 67 beach profile stations that had been established for a beach survey that was under way at the time. Beach Profile (BP) 1 was in the vicinity of the Municipal Dock on the eastern side of the tip of the Spit, and BP 60 was near the base on the western side. Figure 6 in the main report illustrates the approximate positions of these stations. Baseline station numbers, in hundreds of feet + feet and decimals of feet (e.g. 100 + 00.00) have been noted by the beach profile numbers to indicate horizontal distances. Most observations were made during the rising parts of a set of relatively extreme tidal cycles.

BP 1 (100 + 00.00) & 2 (102 + 50.00) - Between the dock and harbor entrance - The foreshore had a very steep slope and was covered with shingle cobble material typical of back beach storm berms elsewhere on the Spit. BP 2 crossed over two pipes which were partially buried. BP 1 was just south of a short upper foreshore groin.

BP 3 (110 + 30.00) - Between old dock pilings and existing dock on the bay side of the Spit - The foreshore was mostly sand covered except for the upper foreshore and parking lot which was cobble covered.

BP 4 (112 + 62.69) - The east (bay side) corner of Lands End Hotel - A lot of flotsam was piled up, extending well under the corner of the building. The major upper storm berm was two rows of pilings back from the corner of the building. More sand appeared on the foreshore slope here than on the open end of the Spit terminus.

BP 6 (113 + 21.99) - On the day of the observation (12 August 1984) a large chunk of humus (probably from the upper soil layer of an eroding coastal bluff) had drifted ashore at this BP. A 3-foot-high storm ridge of cobbles was located under Lands End along the outer row of supporting pilings. Four more storm berms were visible down the foreshore. Only a thin band of sand among the cobbles was visible at mid-foreshore.

BP 7 (114 + 57.29) - The baseline stake was on the foreshore just behind a recent storm berm. A sand strip was near the top of the foreshore. Some of the flat upper berm was in front of the Lands end porch. Two storm berms were visible under the porch.

BP 8 (116 + 57.29) - Near the west corner (Inlet side) of Lands End - The upper storm berm was landward of the baseline stake under the hotel. The upper foreshore sloped straight down from the hotel and was quite sandy with some cobble zones. The lower foreshore was covered with a heterogeneous veneer of cobbles and gravel.

BP 9 (118 + 57.29) - At the west corner of Lands End - Similar to BP 8.

BP 13A (125 + 84.29) - In front of a camping area - The baseline stake was located in a swale between the parking lot and the highest storm berm where windblown sands appeared to have built up. The upper and mid-foreshore were cobbly with four storm berms visible. The lower foreshore was sandy.

BP 15 (128 + 71.66) - At an access road onto the beach - Similar to BP 13A.

BP 16 (130 + 71.66) - At a beach access road and some new construction on the upper storm berm - Foreshore characteristics similar to those of previous stations, though some high-water erosion of camping area fill was evident.

BP 17 (132 + 71.66) & 18A (134 + 71.66) - The baseline stake was on the active upper foreshore storm berm. Two cobbly main storm berms appeared on the foreshore, and a sandy area was seen at mid-foreshore.

BP 19 (134 + 78.20) - Similar to BP 17 & 18A.

BP 20 (137 + 00.64) - Still opposite the camping area - The baseline stake was still on the active cobbly upper storm berm. Three more cobbly storm berms were visible below. A strip of sand was visible below the lowest berm.

BP 21 (139 + 00.64) & 22 (141 + 00.64) - The entire foreshore was covered by cobbles.

BP 23 (143 + 00.64) - Opposite the port building - Similar to BP 21 & 22.

BP 24 (145 + 00.64) - Opposite shops on pilings - Storm berms visible under shops. Baseline stake was on normal high tide storm berm.

BP 25 (147 + 00.64) - Still opposite shops - Foreshore was somewhat less coarse than BP 24.

BP 26 (149 + 00.64) - Upper storm berm was cobbles but the foreshore slope was dominated by sand. Three gravel bands were visible on the foreshore, and some boulders lay at the base of the upper slope. The low tide terrace was distinctive at this point.

BP 27 (151 + 00.64) - The low tide terrace was very distinctive at this point, probably providing significant protection to the upper foreshore. The foreshore slope was dominated by sand and fine gravel.

BP 28 (153 + 00.64) - The baseline stake was in the foreshore slope, below the high tide mark. The upper foreshore was dominated by sand, but the base of upper slope (and top of the low tide terrace) was marked by large cobbles and boulders.

BP 29 (155 + 00.64) & 30 (155 + 00.65) - Similar to BP 28.

BP 31 (157 + 21.21) - Opposite a camping area - The foreshore slope had minor cobble areas, including some gravel zones. No distinctive storm berms were visible.

BP 32 (159 + 21.21) - Opposite shops on pilings - High storm berms were visible under the supporting pilings of the shops.

BP 33 (163 + 21.21) - Just west of shops on pilings - The upper slope and back beach were apparently fill for a parking lot by the shops. The foreshore was heterogenous in composition with no distinctive storm berms.

BP 34 (167 + 21.21) - The upper beach and back beach appeared to be a fill of gravel with silty sand for a parking lot/camping area. Some storm berms on the upper foreshore were dominated by small cobbles with sandy zones between.

BP 35 (171 + 21.21), 36 (175 + 21.21) & 36A (177 + 16.14) - Similar to BP 34.

BP 38 (183 + 66.14) - The low tide terrace was very distinctive with a deposit of boulders and cobbles at the base of the upper foreshore. The foreshore appeared somewhat sandier than the beach beyond (toward the base).

BP 40 (193 + 66.14) - A distinctive pattern of zonation was apparent: a coarse cobble berm at the top of the foreshore with evidence of heterogeneous material overwash, and, proceeding down the profile, zones of medium gravel, fine gravel, coarse sand, and heterogeneous material. Two cobble storm berms were visible on the back beach.

BP 41 (198 + 66.14) - Similar to BP 40 with prominent zonation but not quite so distinctive as BP 40.

BP 42 (204 + 38.53) - The uppermost storm berm dominated the back beach and was used for a crude parking area. The berm material was more heterogeneous than usual with sand and gravel mixed with cobbles. A pattern of gradation down the beach was apparent from large cobbles at the top of the upper foreshore to uniform gravel near the bottom. The apparent sorting by wave energy did not appear as strong as profiles beyond (toward the base).

BP 43 (215 + 97.53) - Similar to BP 42 with somewhat more distinctive sorting on the upper foreshore.

BP 44 (227 + 97.53) - The back beach was dominated by gravel with some indication that the upper "overwash" storm berm of imbricated (overlapping) 4 - 12 in. cobbles was advancing toward the road. Some areas of sand were evident on the foreshore.

Between BP 44 & BP 45 (midway) - A broad flat area of 4 in. + shingles was evidently caused by strong current washover.

BP 45 (234 + 97.54) - Four major storm berms were evident at the top of the beach at approximately the same elevation as the road. The back beach was uniformly gravel and cobbles.

BP 46 (239 + 97.54) - Midway between the end of the sheet pile along the road and the end of the small rubble revetment at the revetment flank - A large storm berm of cobbles was visible at the toe of the revetment. Some fill had apparently been dumped in this area to protect the roadway and the end of the sheet pile.

BP 47 (244 + 97.54) - At the sheet pile - No toe protection existed along this part of the sheet pile. At least six storm berms were discernible across the foreshore which was predominantly coarse gravel. The sheet pile appeared highly exposed during high tide.

BP 48 (246 + 97.54) - At the sheet pile near the south end of the concrete toe protection - The concrete slabs were completely separated and disoriented but were still providing valuable toe protection to the sheet-pile wall. The beach was uniformly gravelly though slightly less coarse than the previous profile (BP 47).

BP 49 (248 + 97.54) - At the sheet pile where previous washouts and partial failure of the sheet pile have occurred - The beach was completely submerged at high tide as it was at the two previous profiles (BP 48 & 47).

Between BP 49 & 50 - Near the start of the rubble revetment where the sheet pile exists behind - The beach is still submerged at high tide and is quite gravelly. There is some indication that the revetment might be subsiding at this point and material on the road had apparently been recently washed over by wave action.

BP 50 (253 + 97.54) - The beach began to widen northward away from the sheet pile and was still quite gravelly.

BP 51 (258 + 97.54) - The beach below the revetment was gravelly without recognizable storm berms and was wider than the profile beyond (BP 52).

BP 52 (263 + 97.54) & BP 53 (268 + 97.54) - The beach was somewhat more narrow than BP 51.

BP 53A (273 + 94.58) - Very little beach existed at high tide. Some revetment stone was mixed into the storm berm at the toe of the revetment.

BP 54 (275 + 86.22) - Very little beach at high tide. Sand was mixed with a cover of cobbles on the upper foreshore.

BP 55 (279 + 86.22) - The beach widened somewhat from the previous profile.

BP 56 (283 + 59.31) - From this profile to BP 58 the beach was relatively uniform and wide. The toe of the revetment was buried.

BP 57 (288 + 89.55) - At the piling stubs of the last (5th) beach groin remnants - The high tide beach appeared to be in stable equilibrium with storm berms of cobbles slightly larger than profiles beyond.

BP 58 (295 + 39.55) - About 25 ft south of pilings of a groin remnant - The beach was mostly fine sand with intermittent storm berms of gravel. The groin pilings did not appear to be affecting the beach.

Between BP 58 & 59 - At groin remnants at this location there was a 3-ft drop south of the groin, with a locally narrow and steep beach extending toward BP 58. The beach below the revetment was submerged at high tide.

BP 59 (305 + 39.55) - Approximately 200 ft northwest of the first timber groin remnant - The area appeared to be affected by the downdrift groin with a cobble-gravel storm berm near the toe of the revetment and little evidence of zonation on the gravel covered foreshore.

BP 60 (315 + 39.56) - A very wide low tide terrace existed at this location with six cobble storm berms discernible on the upper foreshore below the revetment.

APPENDIX D: Sediment Transport Analysis

SEDIMENT TRANSPORT COMPUTATIONS

1. The use of the wave transformation model to estimate longshore wave energy flux at each shoreline grid cell along Homer Spit was discussed in detail in Appendix B and summarized in the main report. The only additional points that will be made in this Appendix relate to similar future efforts that might be made to refine these estimates. The available hydrography in this preliminary study was limited to NOAA boat sheet soundings with reference to MLLW. No survey data above MLLW were made available in time for incorporation into the numerical grid and continued computations simulating higher water levels. The grid was arranged also to simulate the transformation from transitional depths in Cook Inlet, and computational adjustments were required to resolve the location of the breaker zone in very shallow water. Future simulations might take further steps to define surf zone characteristics during varying stages of the tide. Any and all efforts made to verify these future estimates with field measurements would be of significant value. Continued visual observations and wave gaging should be vigorously pursued. Measurements with a directional wave gage placed offshore of the area of primary concern, relatively near the surf zone would also be helpful in verifying the longshore energy flux estimates. Periodic resurveying of the previously established beach profile stations would be extremely important in measuring the beach's actual response to incident wave energy.

BEACH PROFILE CHARACTERISTICS

2. The 67 beach profiles that were surveyed in August 1984 were plotted and are included in Supplement 1 to this Appendix. The following discussion provides a general description of the trends observed from these plots. Since only a single set of these profiles was available in the course of this preliminary study, no analysis of measured changes was possible.

3. Profiles 8 through 12 have above water (MLLW) portions of the beach at steep slopes on the order of 1:10. The below water portions of the profiles have a steep, typically concave, upward shape. This type of profile is expected at the distal end of a spit with deep water offshore. The submerged profile approaches an angle of dynamic repose for sediments subjected to substantial wave and current action on the order of 10 - 15 deg. This is considerably steeper than the angle of repose for sediment in still water, which is on the order of 30 deg.

4. Profiles 13 through 17 have similar above water slopes, although somewhat milder, on the order of 1:12. The underwater portions shift dramatically to an upward convex profile with much milder slope offshore. The offshore slopes of the profiles generally get milder in proportion to the distance of the profile from the distal end of the Spit. The convex shape of the profile suggests an abundance of sand in this area which may mark the start of a region where finer portions of the sediment transported longshore toward the tip leave the Spit littoral zone and migrate offshore.

5. Profiles 17 through 23 are similar in form to those noted previously but with milder transitions and more moderate slopes. Above water profiles appear to have stabilized at beach slopes ranging from 1:8 to 1:12, while below water profiles continue the trend of milder slopes with distance from the distal end. Large undulations in offshore profiles 17, 18, and 19 are noted in water depths around -50 MLLW. These may be relict bars or shoals from periods of lower sea levels.

6. Profiles 24 through 29 have similar above water profiles to previous profiles, but below water slopes are not far from linear on the order of 1:75 out to around 3,500 ft offshore (with exception of some bar formation just beneath MLLW). This area appears to be a transition zone between the profiles with an abundance of fine sand and the zone of profiles that take on an equilibrium form of upward concavity (discussed later in this Appendix).

7. Profiles 30 through 32 again have similar above water topography, but below water profiles consistently are concave upward with relatively mild slope. The profiles steepen beyond 3,000 ft offshore, a feature which is presumably not related to present littoral processes.

8. Profiles 33 through 51 have similar above water profiles, but below water profiles appear to be slightly steeper to about 2,000 to 3,500 ft offshore where slopes become mild again. An offshore bar of some sort appears at this point with a steep drop to Cook Inlet depths beyond. This bar defines the geological base of the Spit.

9. Profiles 51 through 60 continue the steep above water trend with slopes on the order of 1:8, while the offshore profiles appear to have an equilibrium shape concave upward. Undulations in the submerged profile are possibly relict bars formed by wave action in recent or geological past depending on their depth.

EQUILIBRIUM PROFILES

10. In terms of the Homer application, submerged beach profiles in equilibrium in terms of onshore-offshore transport of sediments have been found on many diverse coasts around the world to follow the general form expressed by Bruun (1954):

$$y = Ax^{2/3}$$

where y is the depth, and x is the horizontal distance offshore from the waterline. Moore (1982) has documented that in such profiles the A factor is a function of grain size. The grain size (median particle diameter) along the low tide terrace of the western (Inlet side) shoreline of Homer Spit ranged in August 1984 from 0.12mm to 0.30mm, suggesting an A coefficient from 0.07 to 0.10, according to Moore (1982). Theoretical equilibrium profiles with these upper and lower depth limits have been superimposed on plots on the Homer beach profiles that were surveyed in August 1984, which are included as Supplement 2 of this Appendix. The waterline, or the y=0 elevation, was taken as MLLW (or 0.0 elevation) in this preliminary study since the 18.1-ft diurnal tidal range was beyond prior experience with this approach, and the surveyed profiles could be readily seen to depart dramatically from the $x^{2/3}$ shape. The continuously submerged beach profile beyond MLLW was thought to perhaps approach an equilibrium shape where it was relatively stable in the onshore-offshore direction. The Spit had not been subjected to any major storms for 2 months or more in August 1984, so the beach was presumably adjusted to milder, more continuous summer weather at the time the profiles were surveyed. The comparison of actual versus theoretical equilibrium profiles might thus reveal areas where offshore losses from the Spit could be significant.

11. The beach slope below MLLW in the vicinity of the distal end of the Spit, from BP 1 to approximately BP 29, was seen to be significantly steeper than the equilibrium shape. The deviation from the theoretical equilibrium shape increased toward the tip on around to BP 2A near the harbor entrance channel on the eastern side of the Spit. The measured profiles from BP 30 on toward the base of the Spit appeared to be close to equilibrium with their relative conformity increasing toward the base. These trends can be interpreted to show that there may be significant offshore loss of beach material at and near the tip of the Spit where the foundation of the Spit narrows and the deep water of central Kachemak Bay comes closer and closer. The beach slope right at the tip, off Lands End Hotel, is on the order of 12 deg from horizontal, or 1:5, which is extremely steep in terms of beach slopes elsewhere. The increasing tidal currents at the tip probably play a substantial role in carrying material away from the beach, either to be lost in the 100+ -ft-depths off the tip on flood tide or to the Archimandritof Shoals on ebb tide (see Figure 3, main report). The gravel and cobbles found on the beaches at Lands End Hotel are heavy enough to stay in the tidal prism and be carried around the tip, though some portion of this coarse material may also be lost. The tip of Homer Spit clearly exists in a high-energy environment, and its apparent long-term stability, as revealed from aerial photos, can only be attributed to a continuous supply of longshore sediments from the body of the Spit. A depletion of this supply by erosion control measures along the body of the Spit would probably be accompanied with dramatic shoreline retreat at the tip where the Spit is most developed.

12. The erosion problems being addressed by this study extend approximately from BP 44 to BP 58. The wave transformation analysis revealed this area to be just downdrift from a "null point" or zone of wave energy divergence, apparently caused by the refractive effect of the deltaic hydrographic feature off Beluga Lake. The conformity of the beach profiles below MLLW to a theoretical equilibrium shape indicates that the beach apparently responds to the sediment deficit over the long term by retreating uniformly. Artificial restraint of this uniform retreat would probably result in steepening and departure from the equilibrium shape.

APPENDIX D: Supplement 1

HOMER SPIT, ALASKA

ORIGINAL BEACH PROFILES

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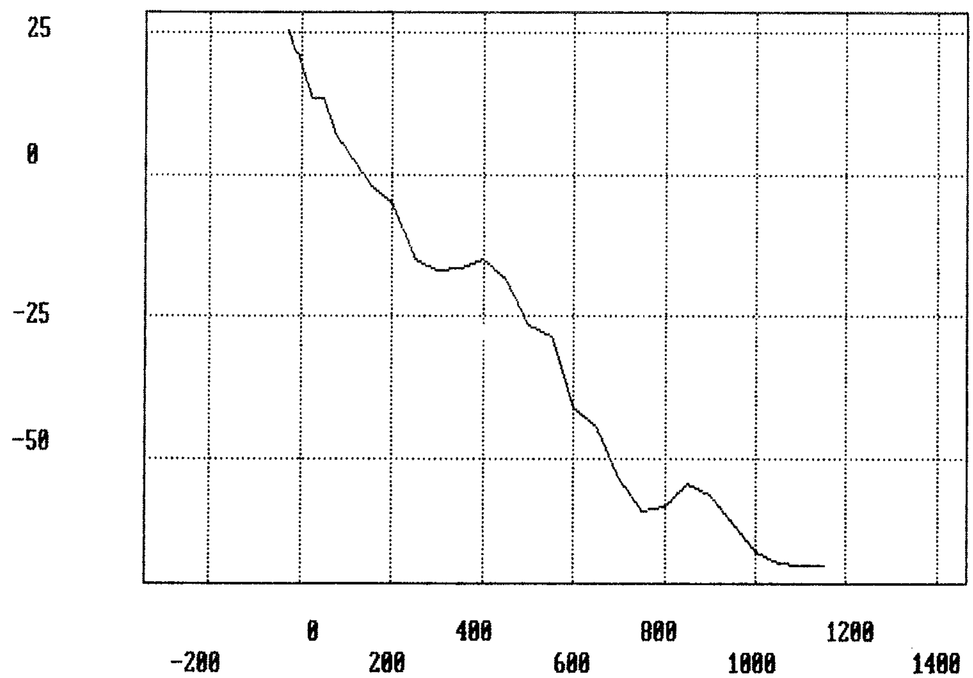

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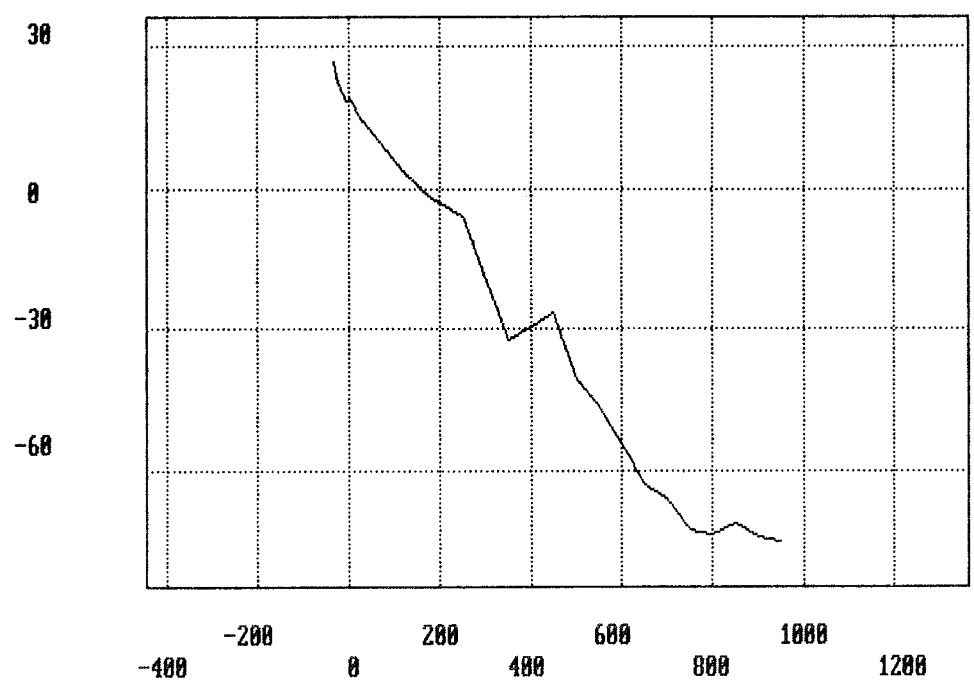

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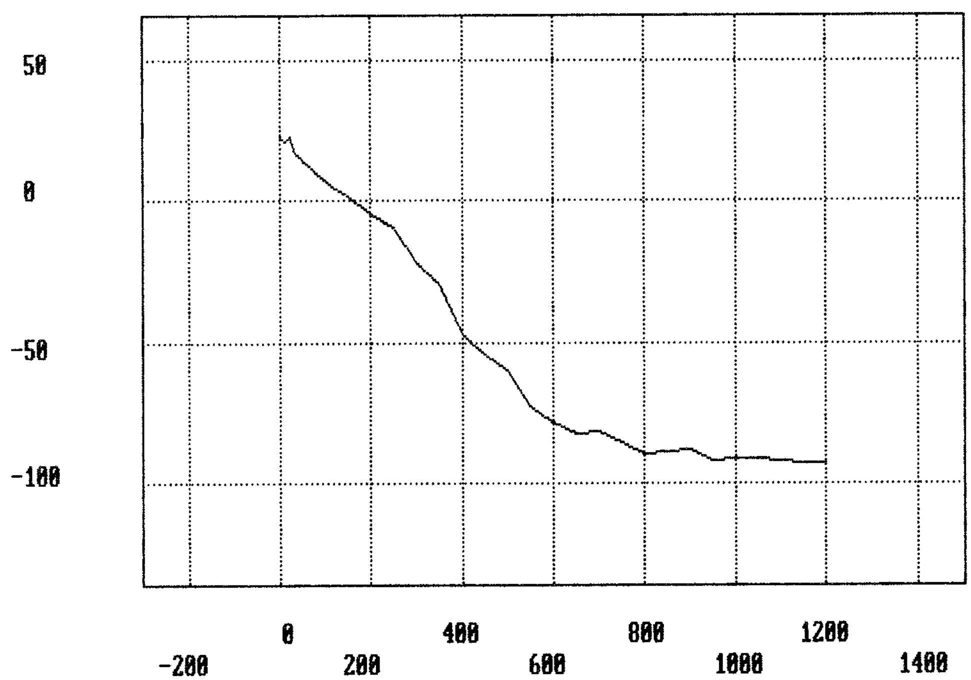

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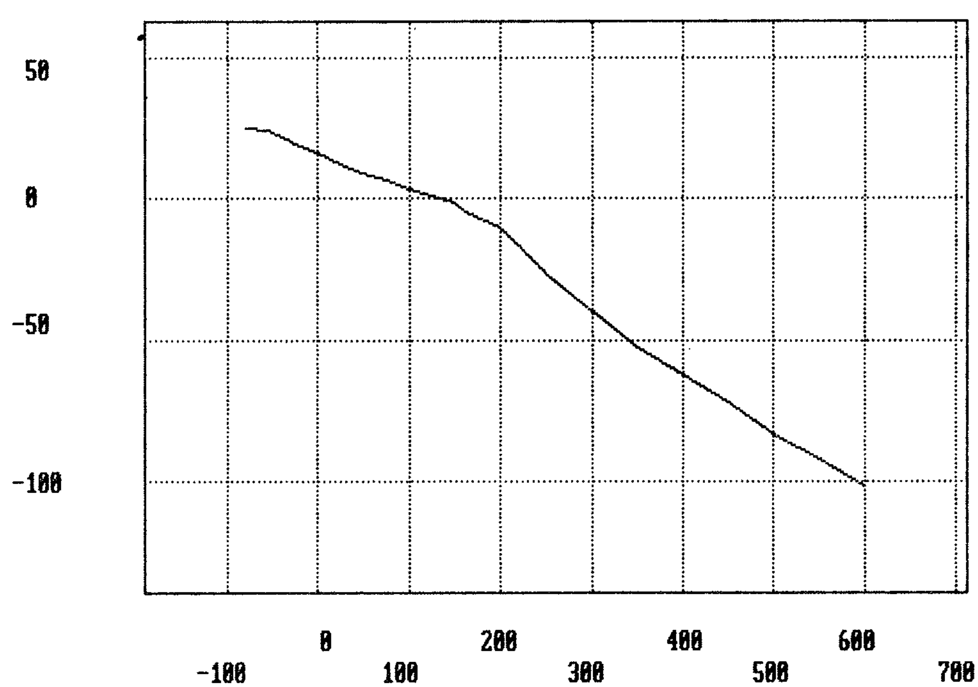

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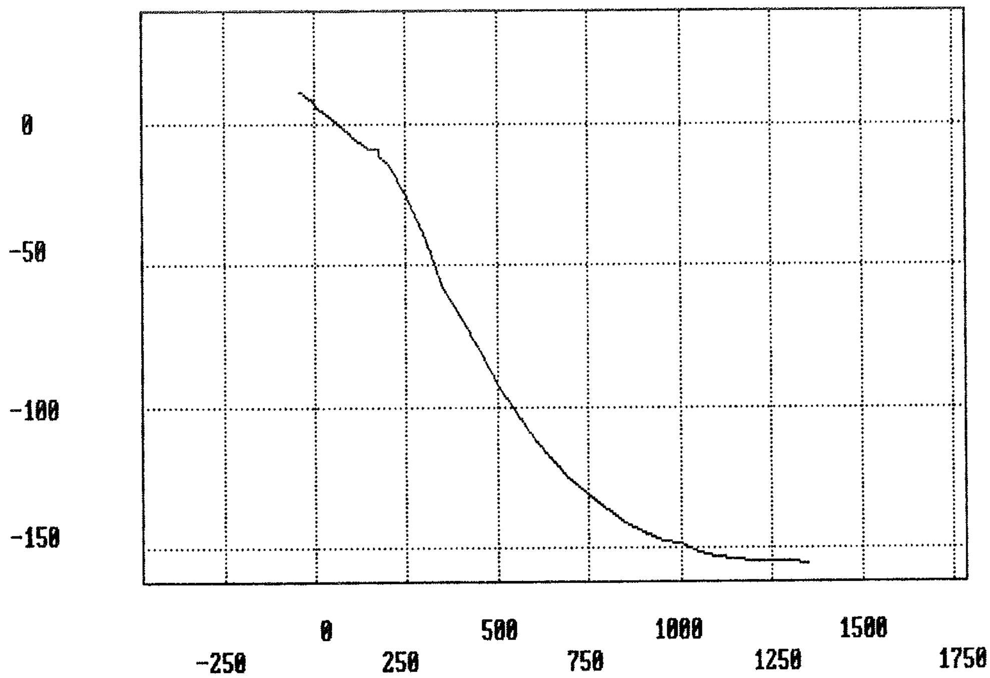

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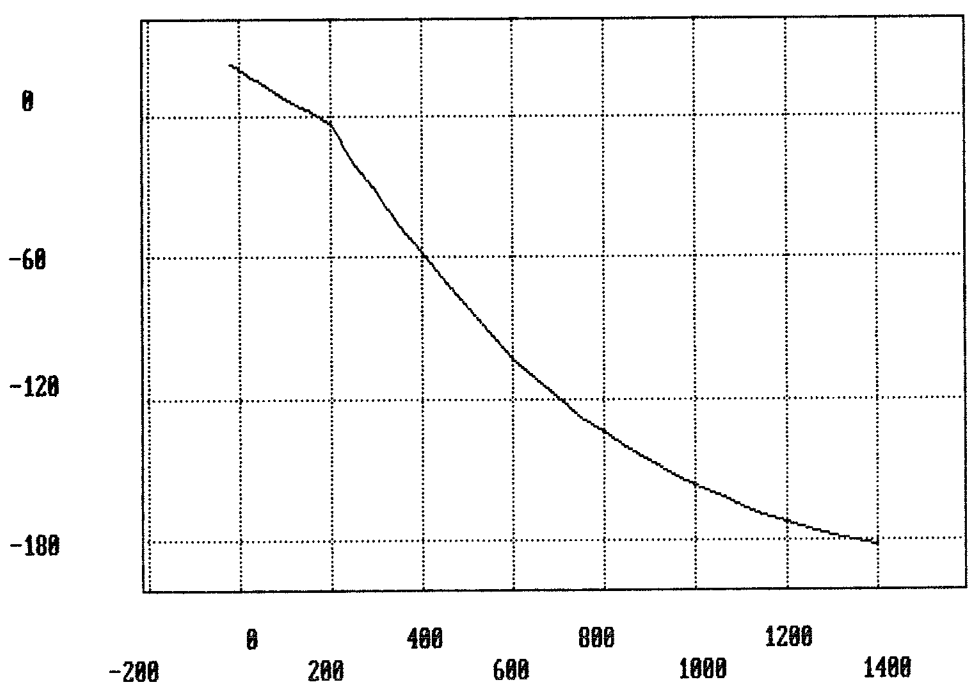

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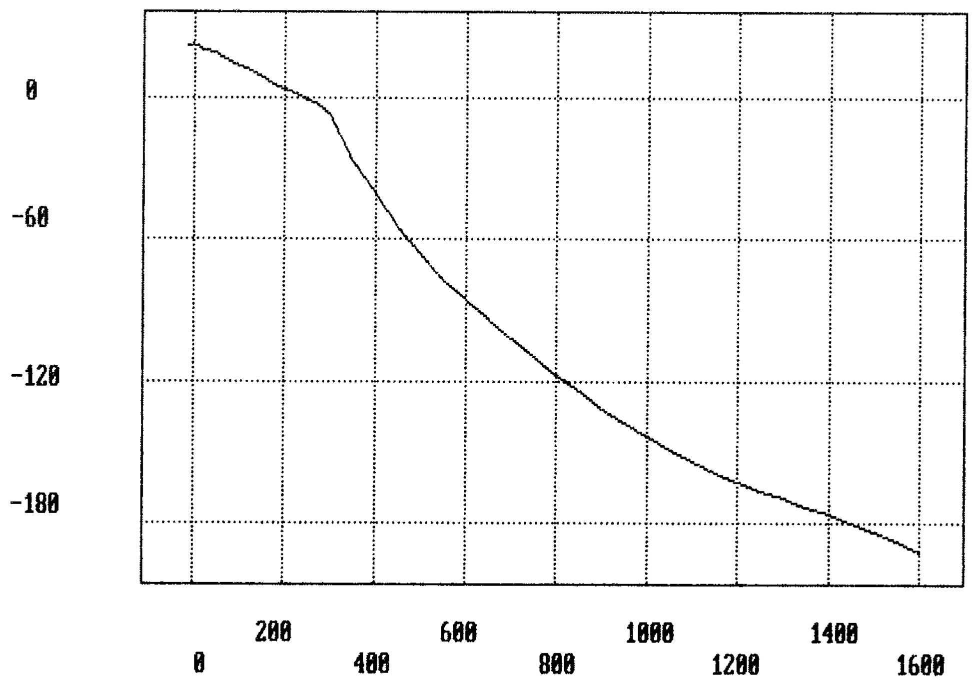

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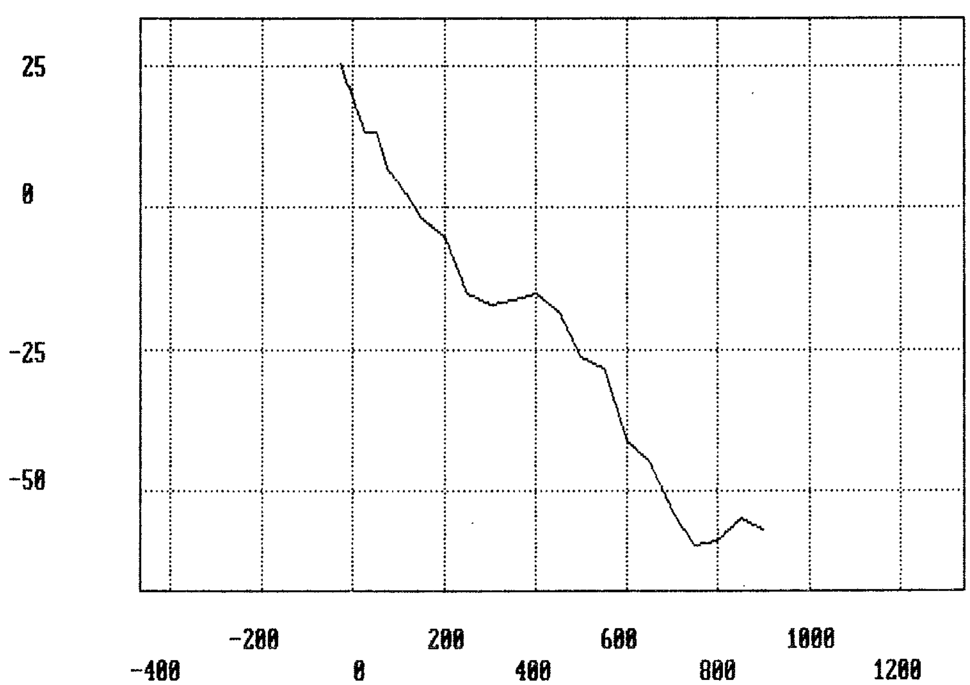

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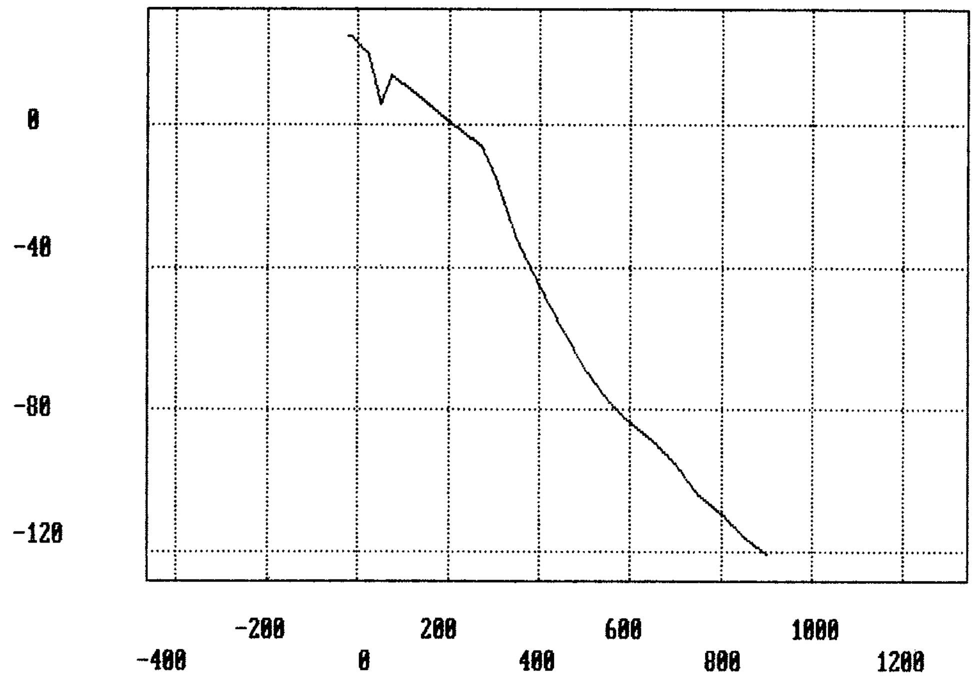

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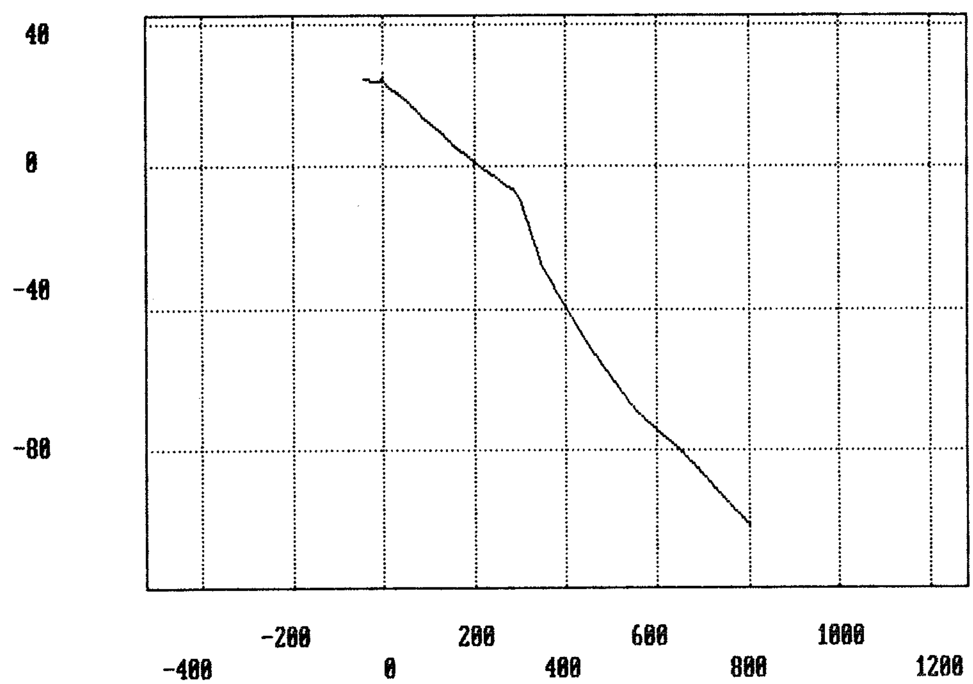

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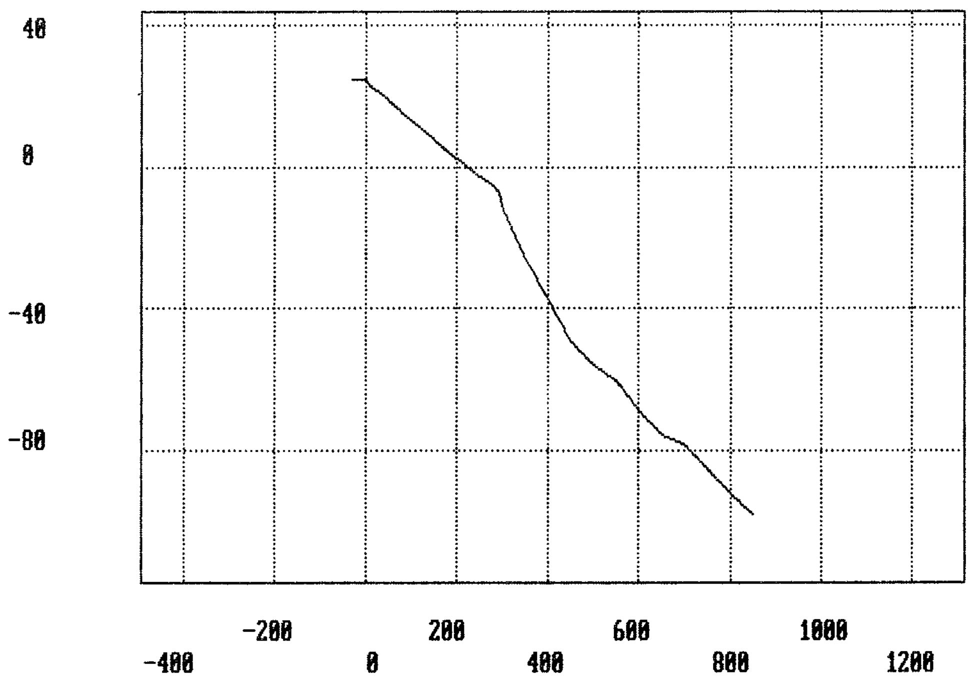

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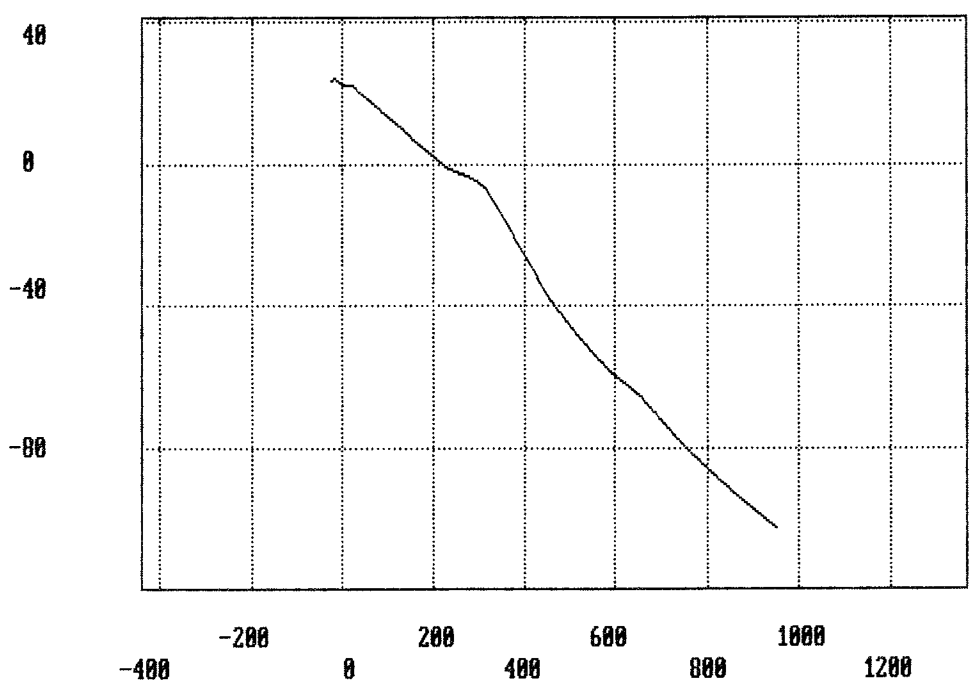

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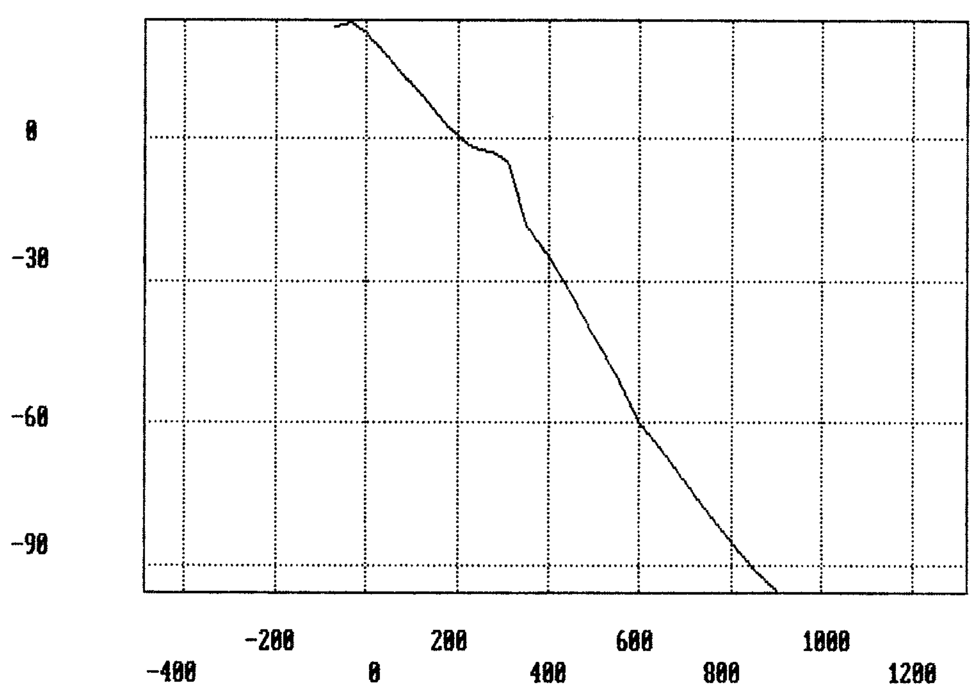

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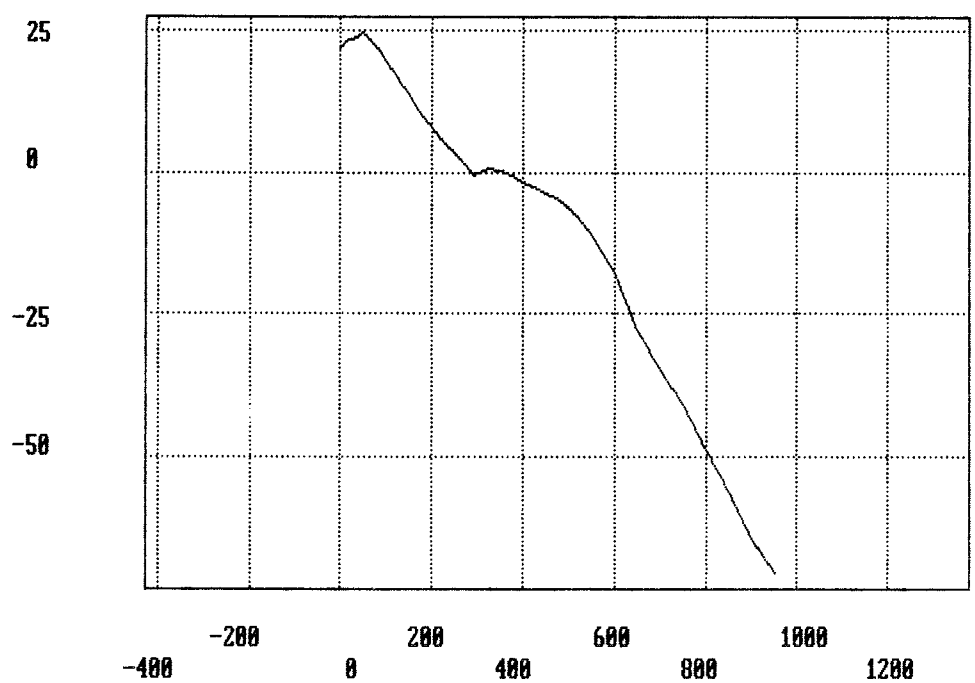

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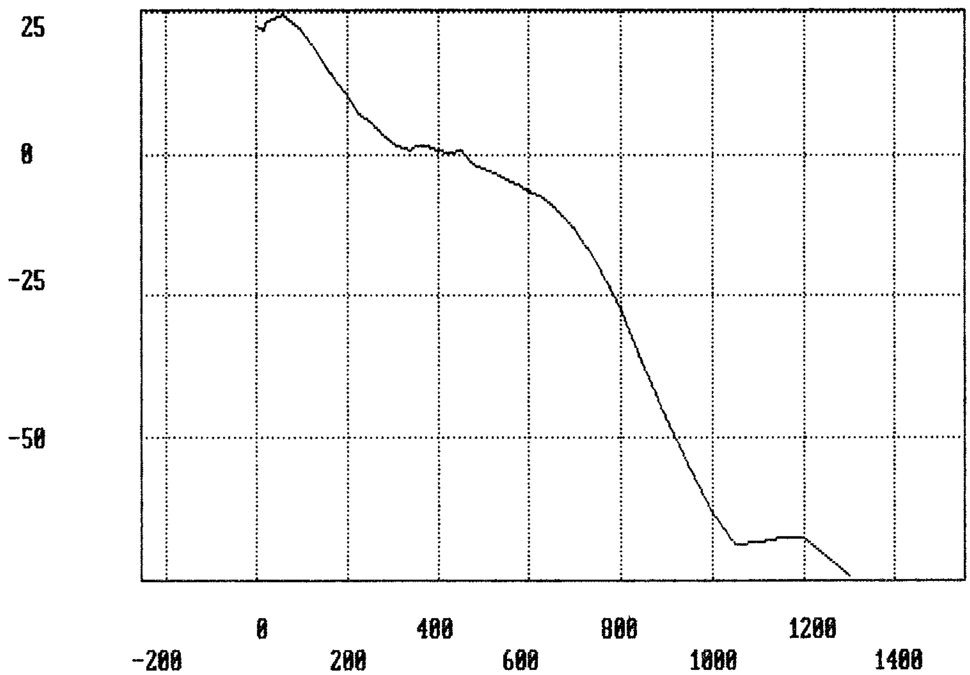

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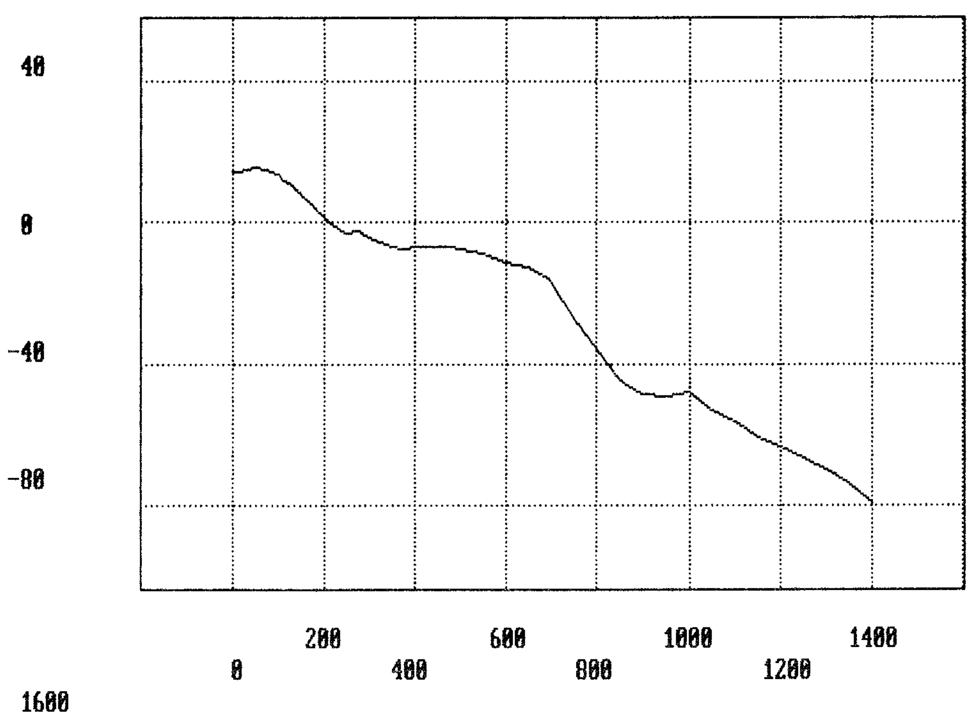

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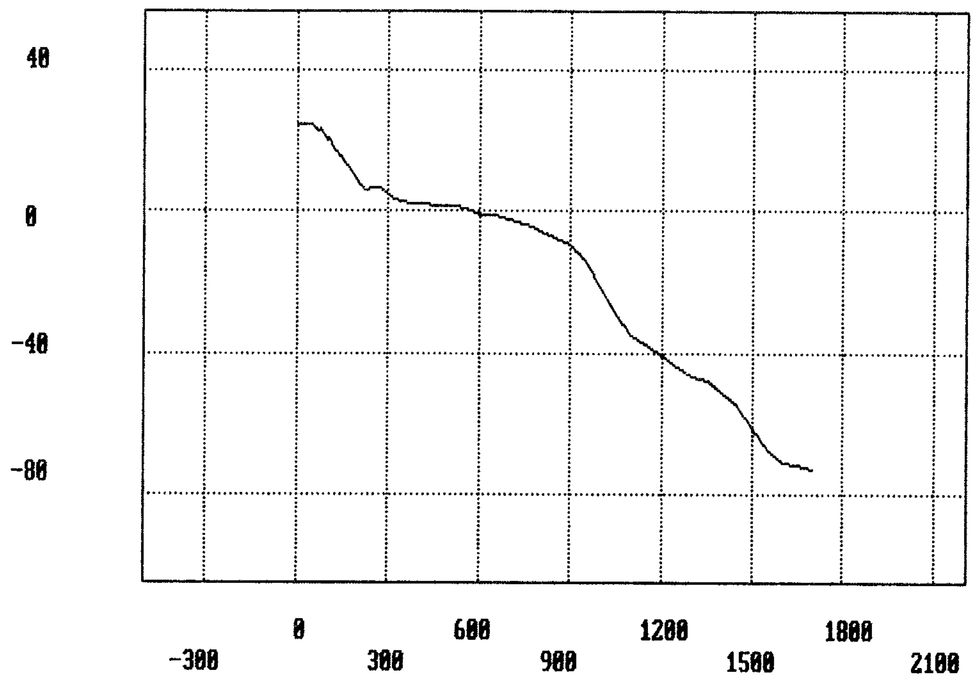

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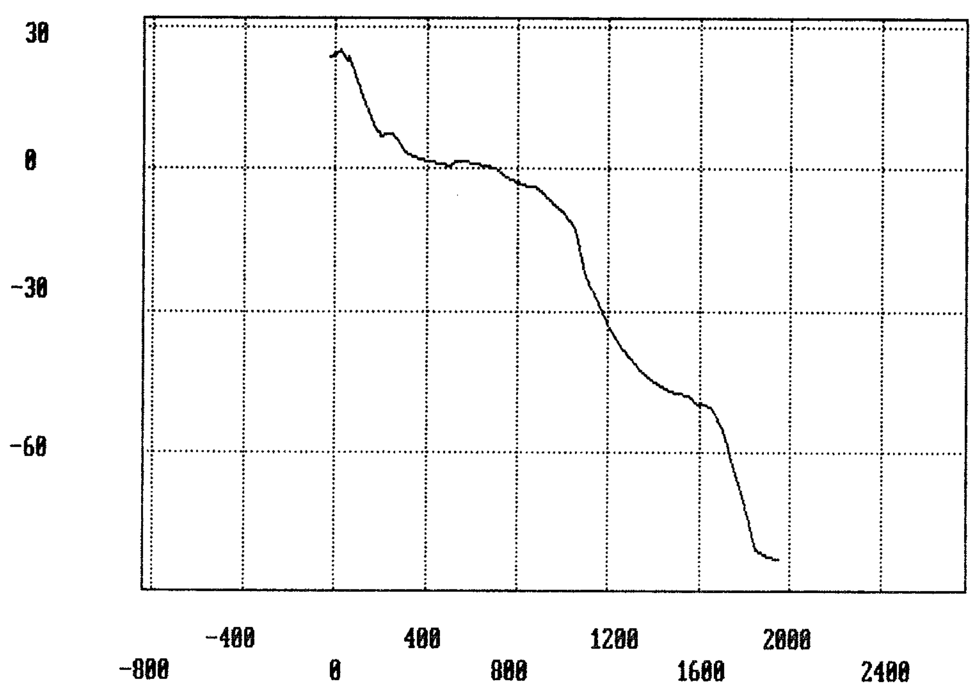

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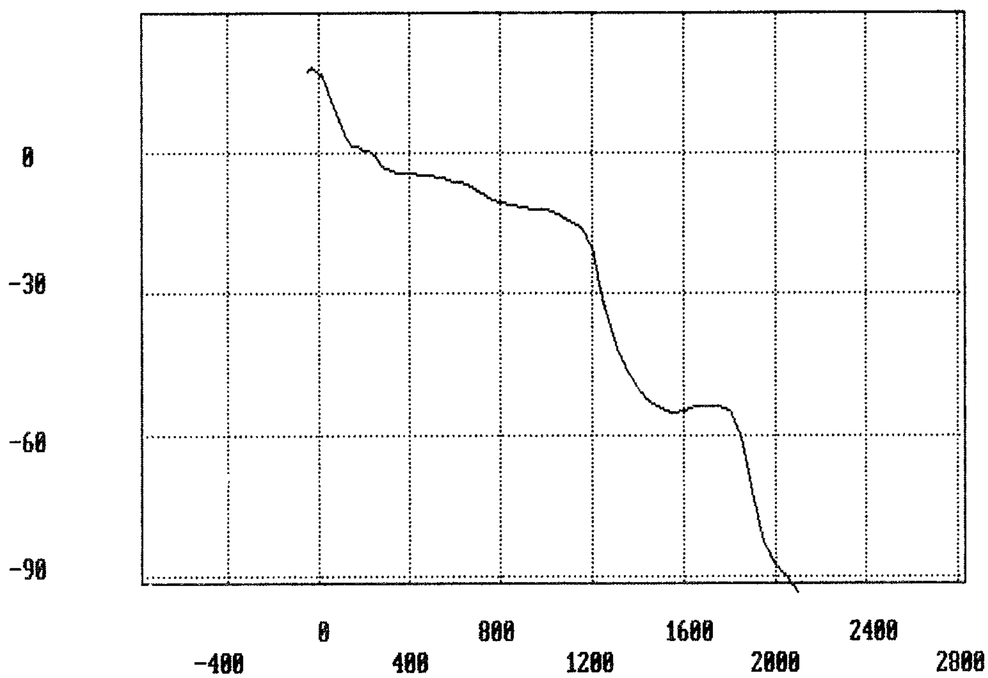

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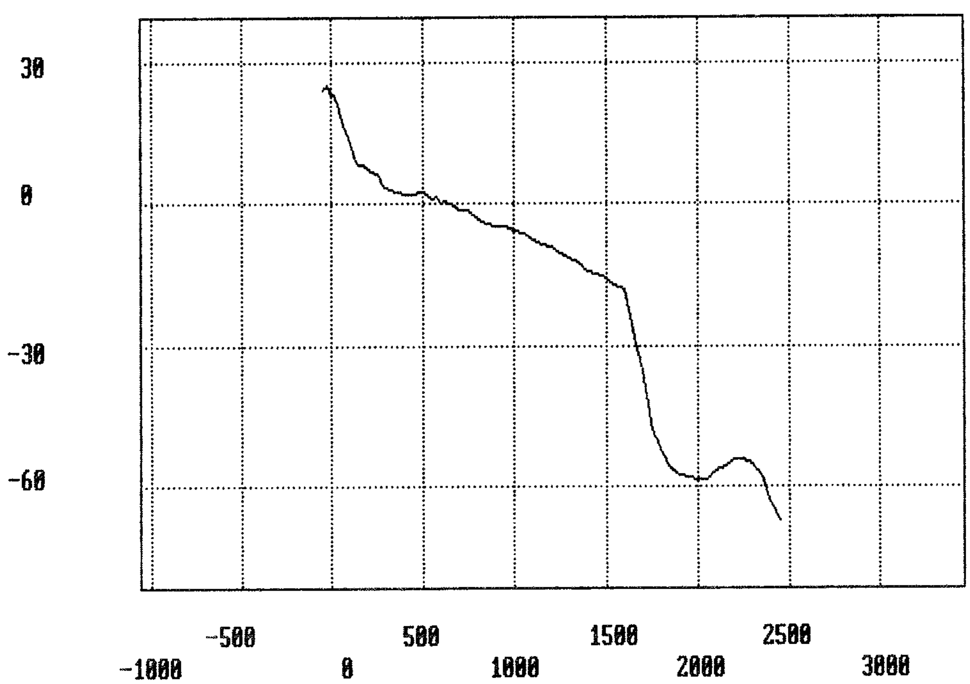

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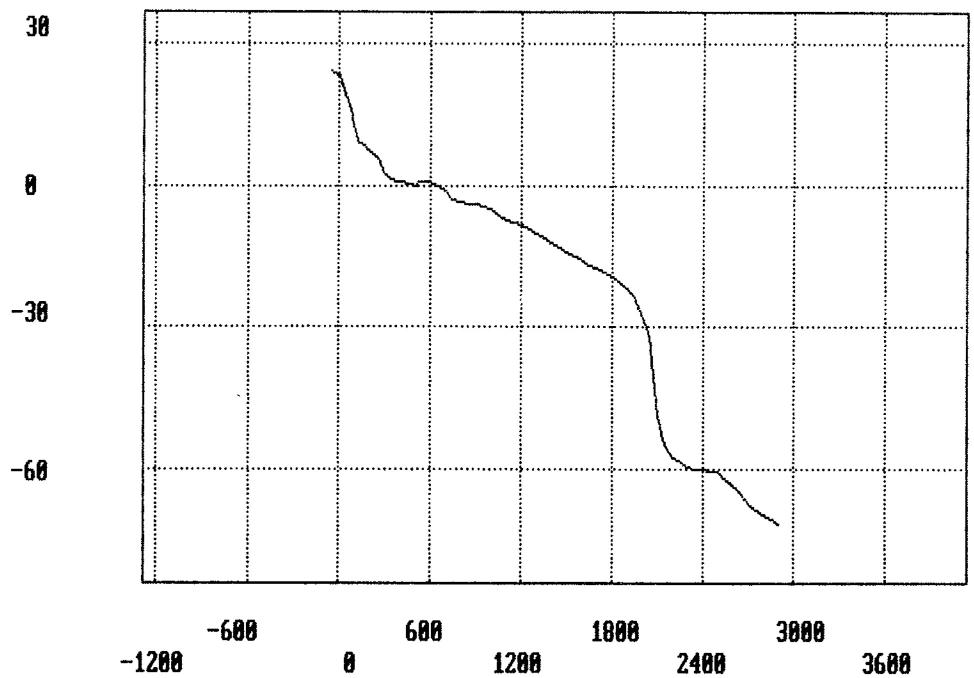

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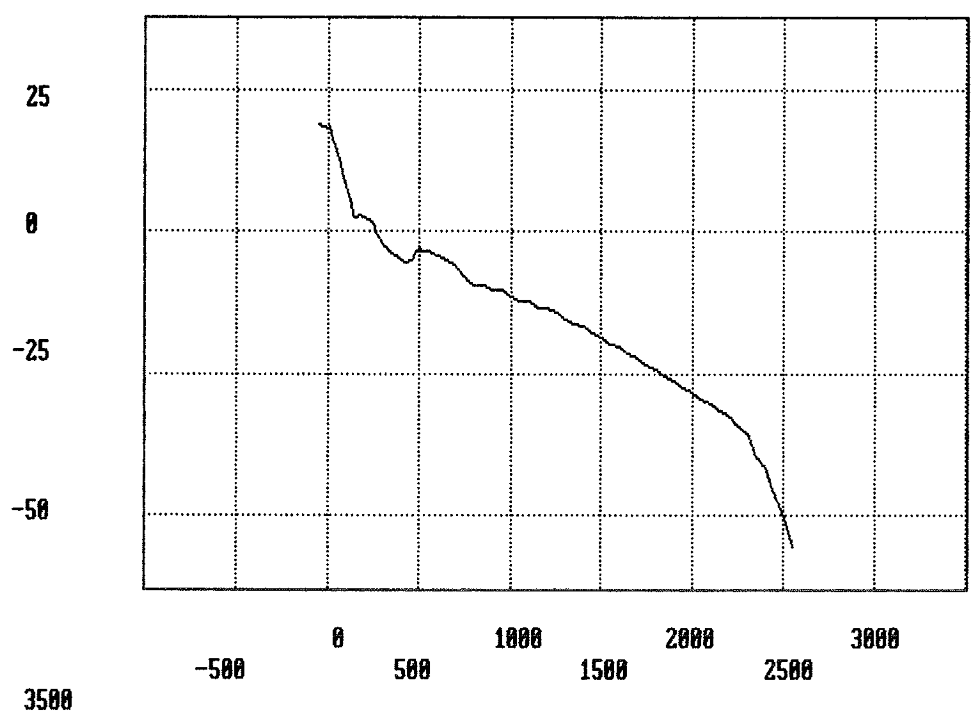

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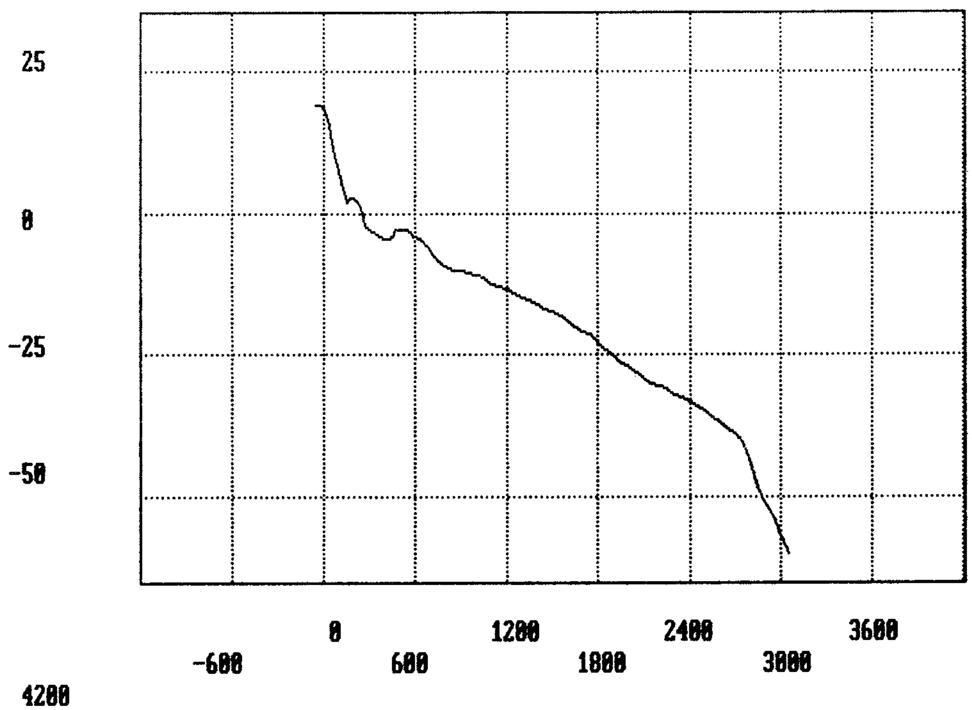

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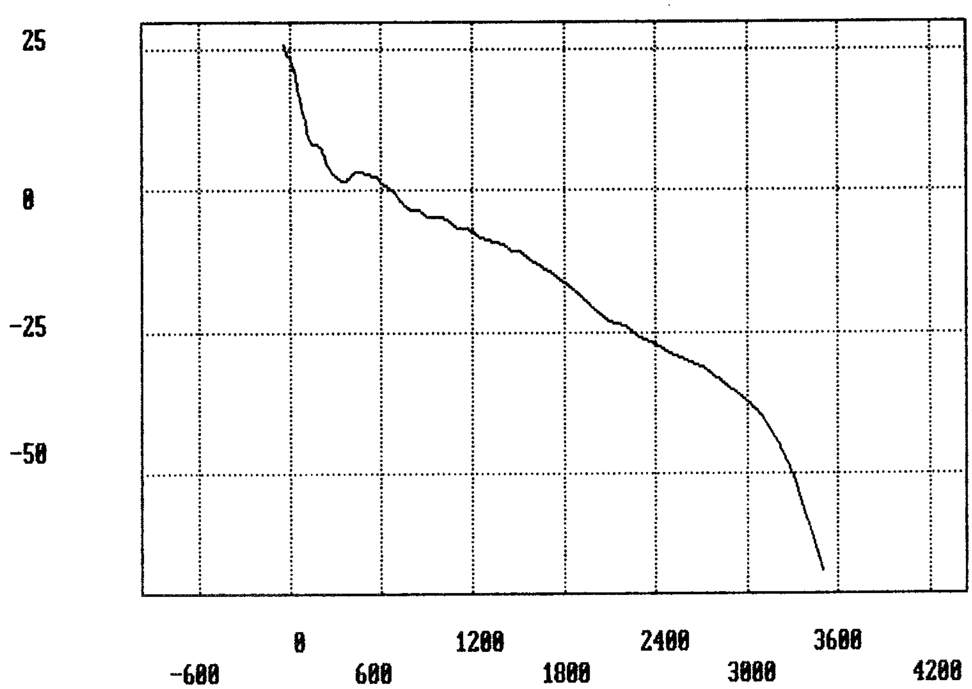

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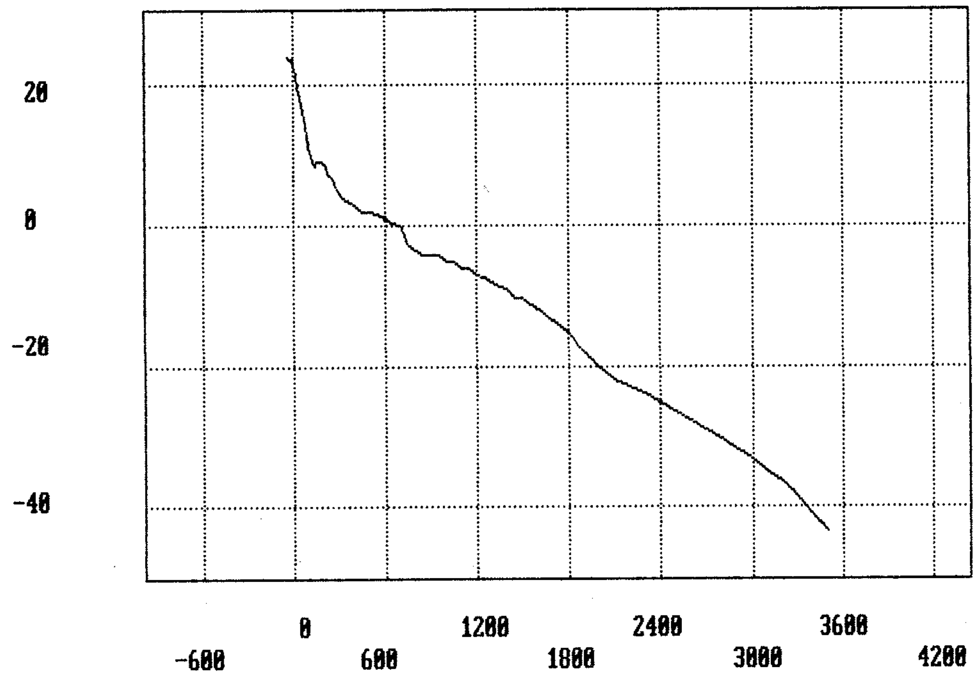

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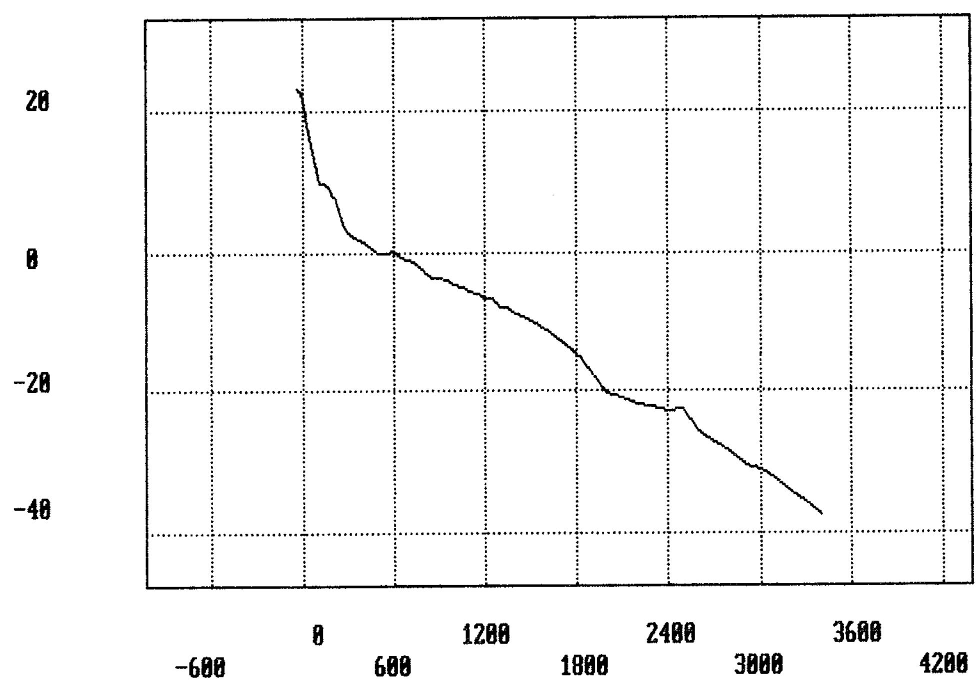

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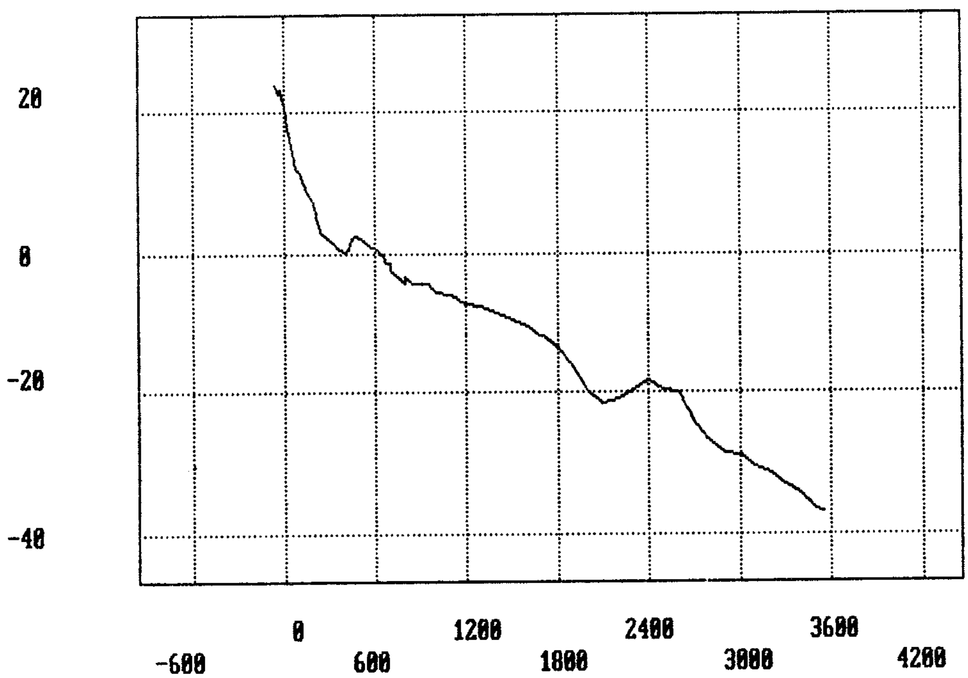

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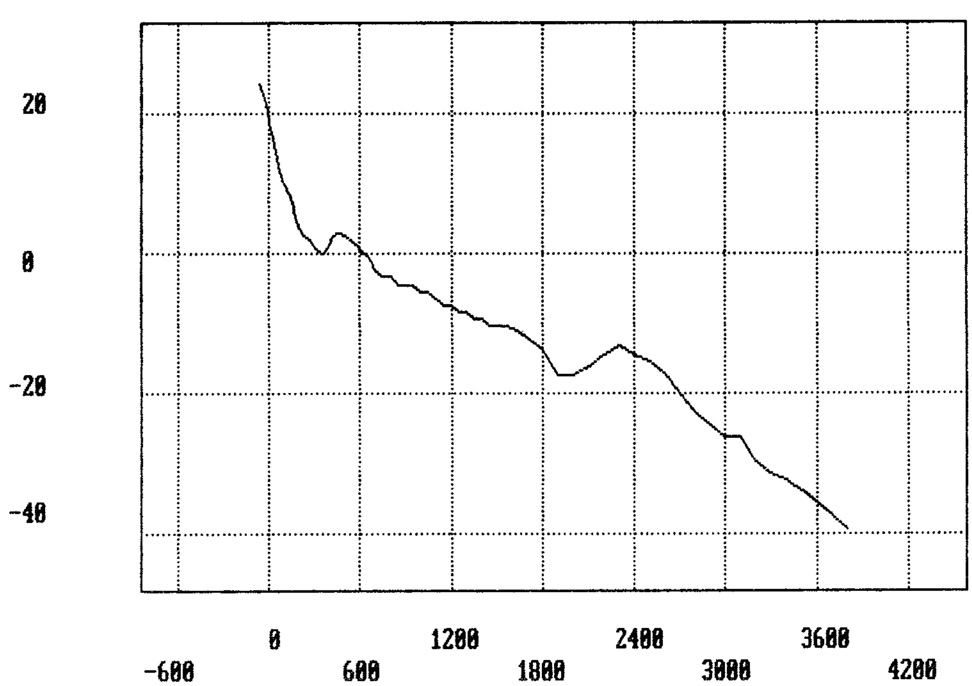

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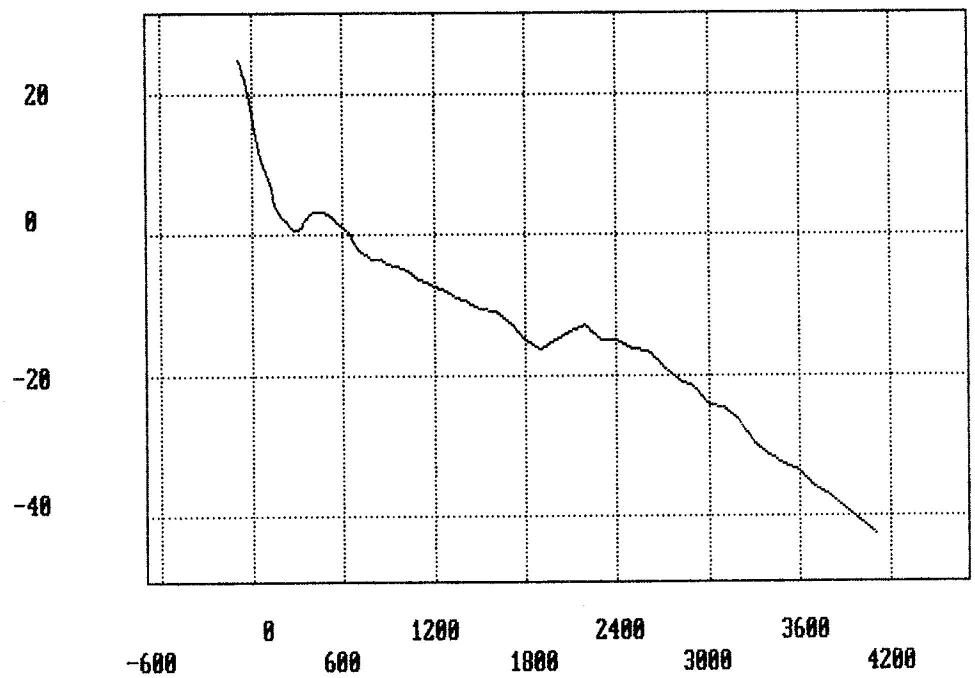

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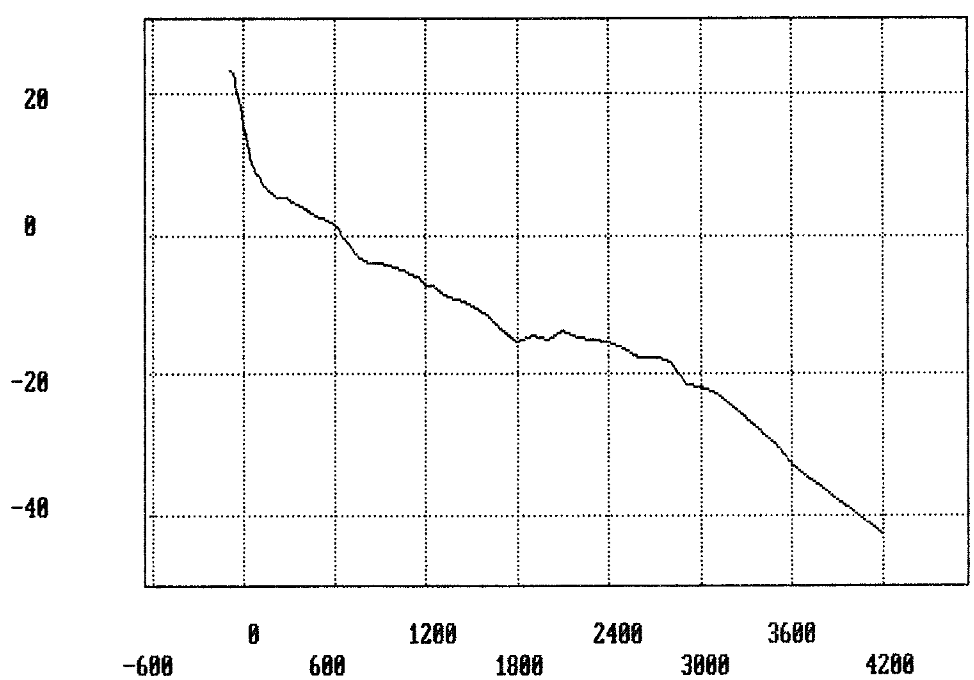

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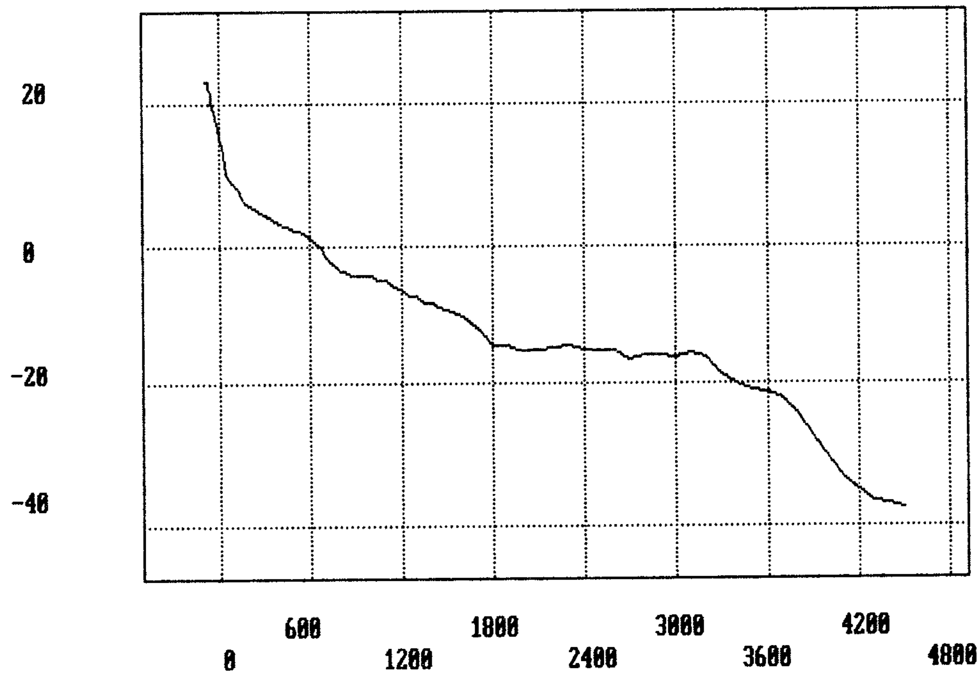

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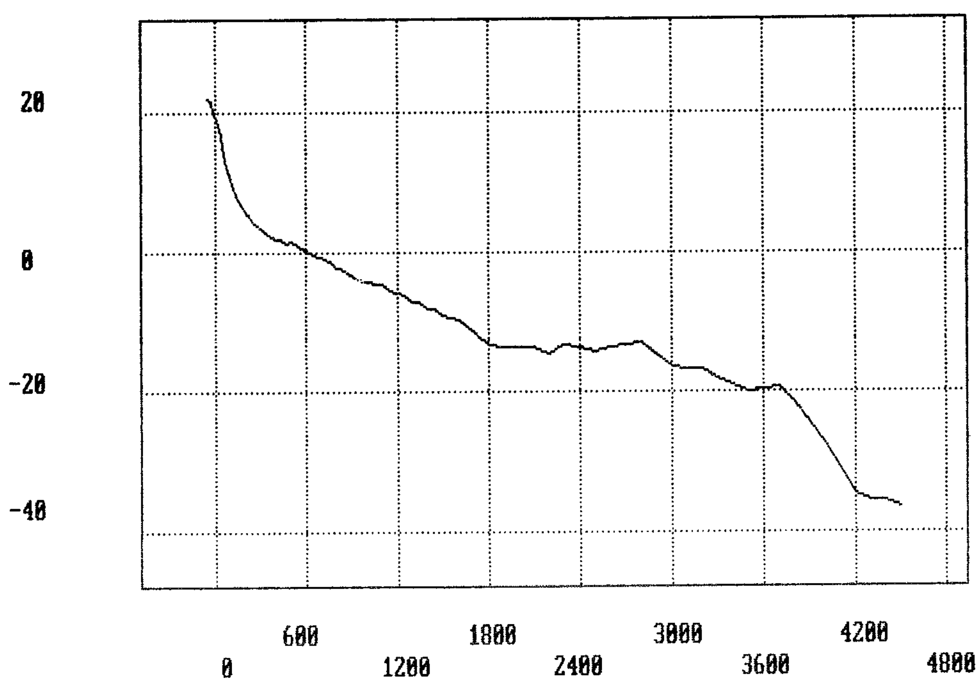

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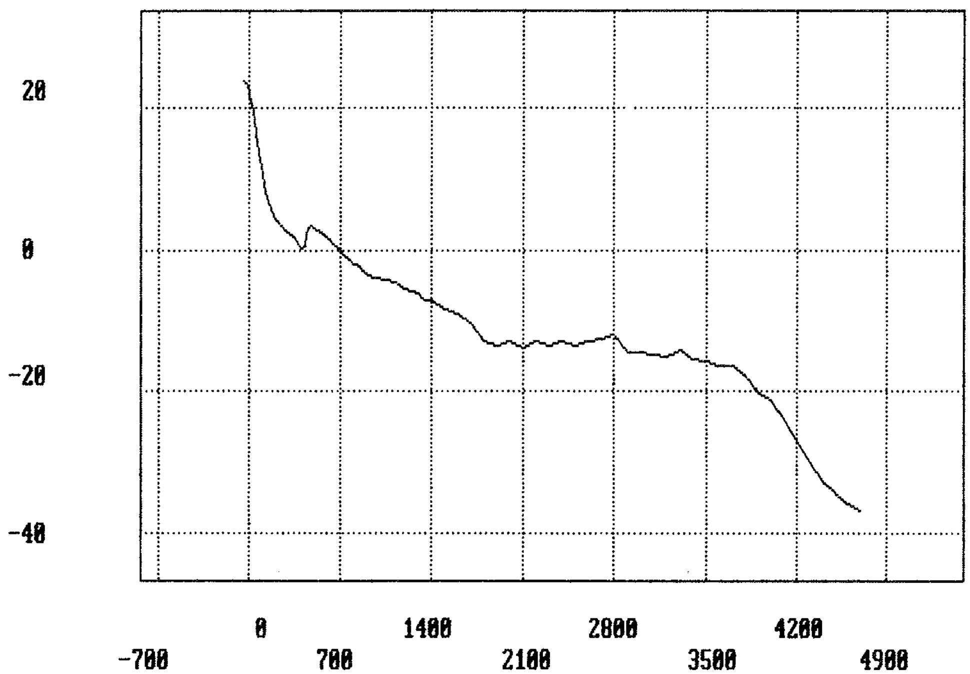

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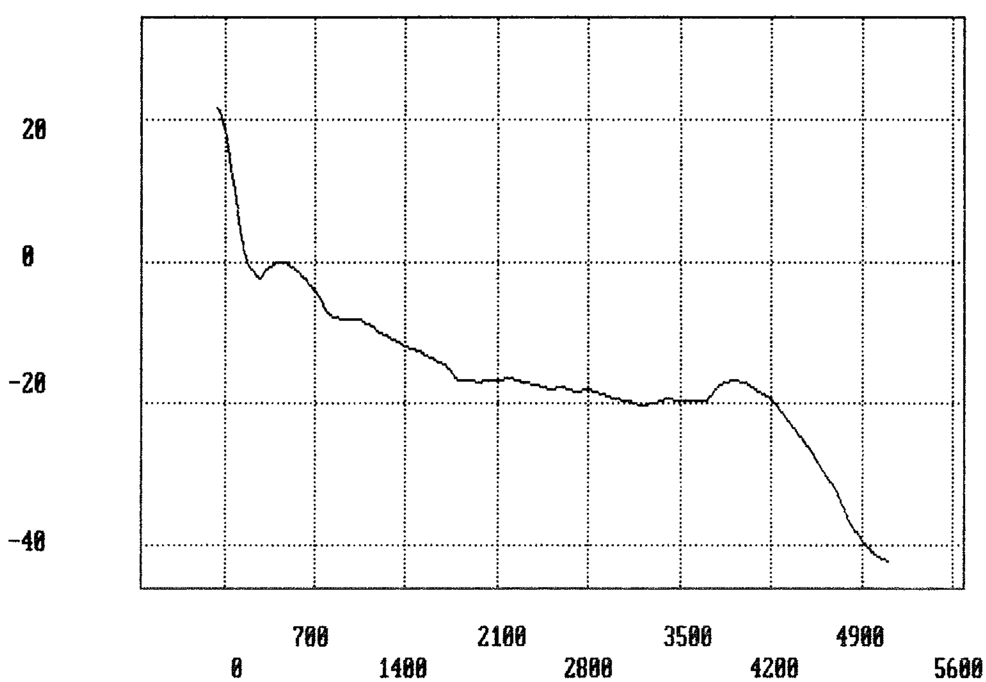

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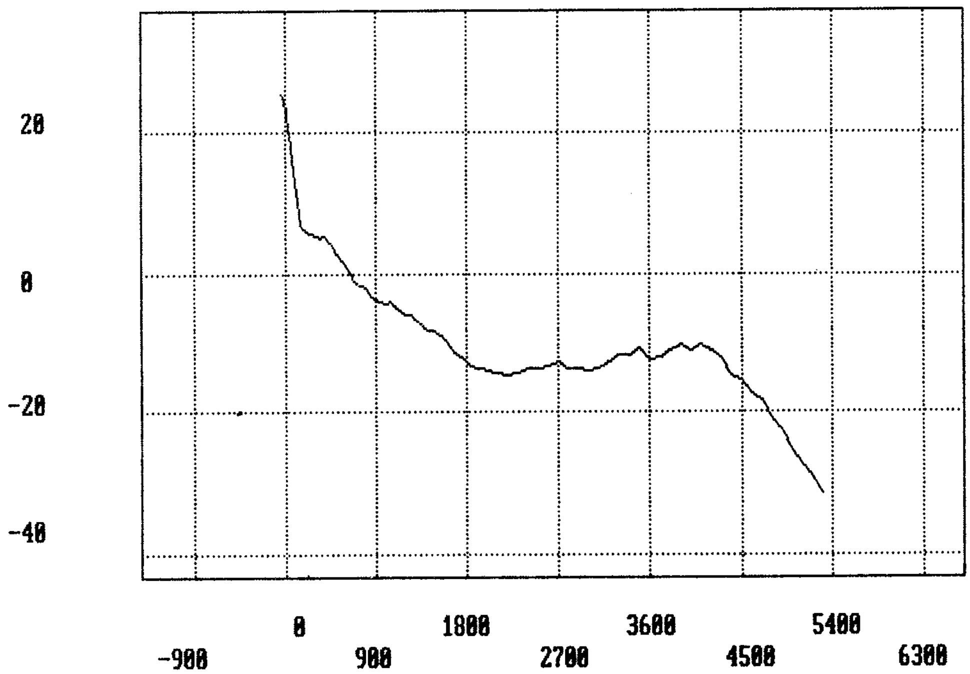

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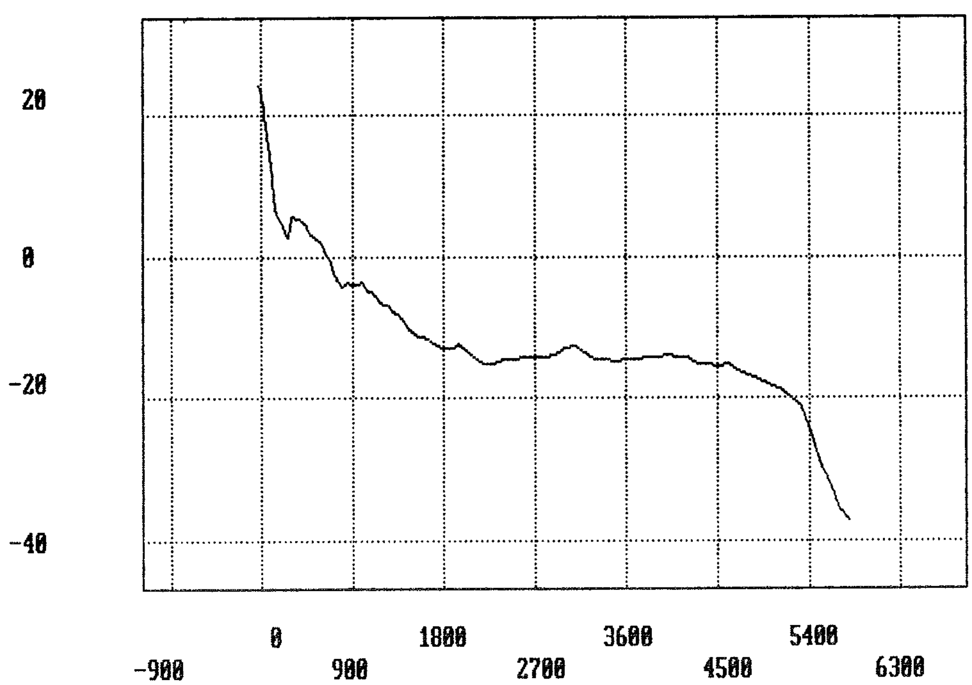
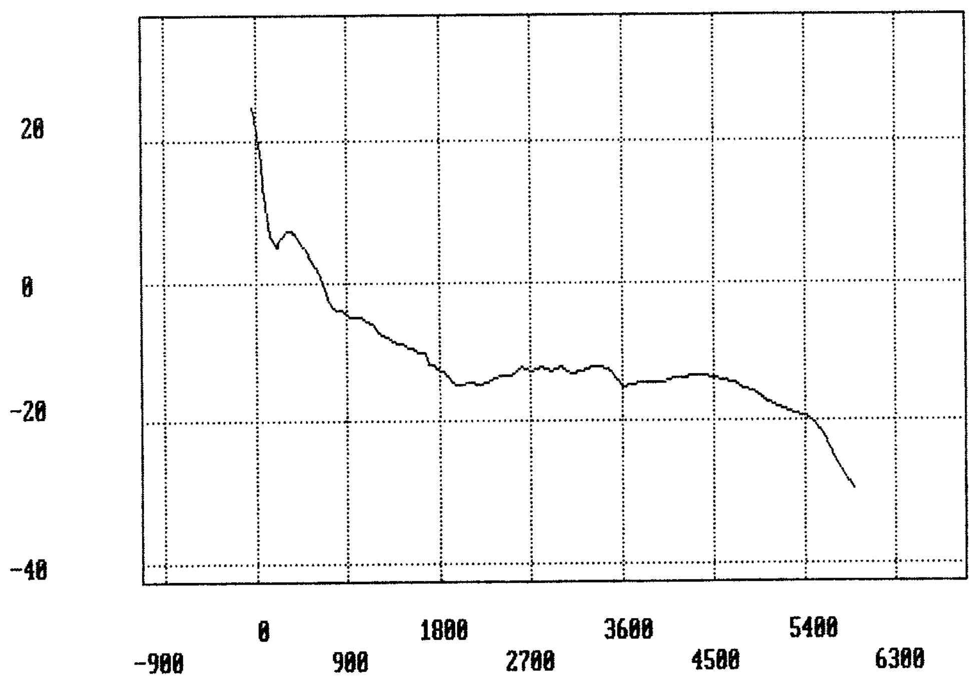
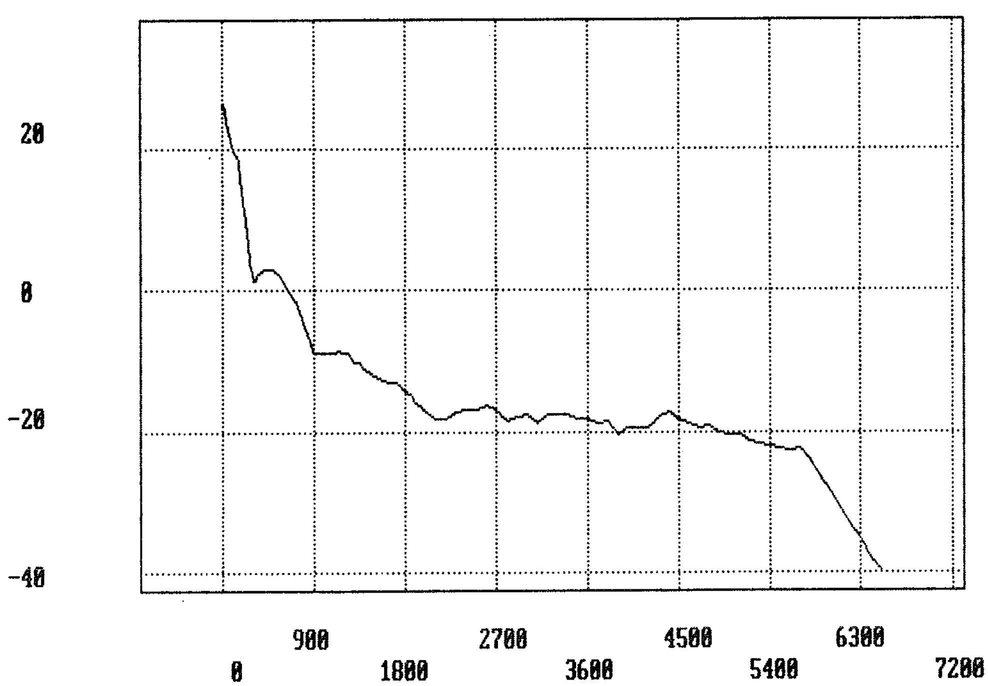


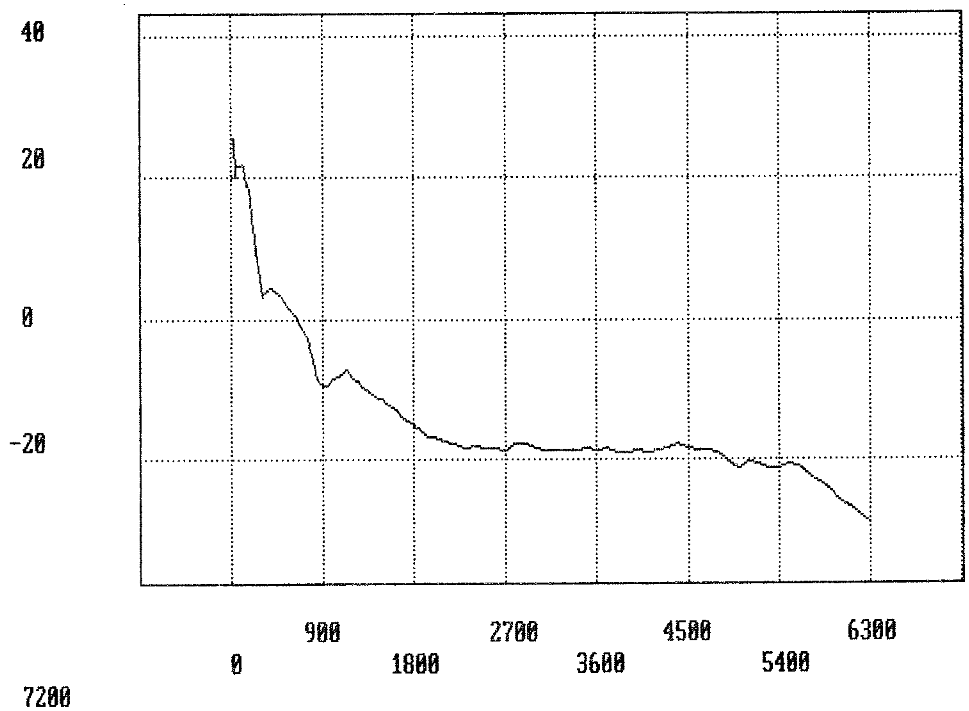
* STA: 175+21.21



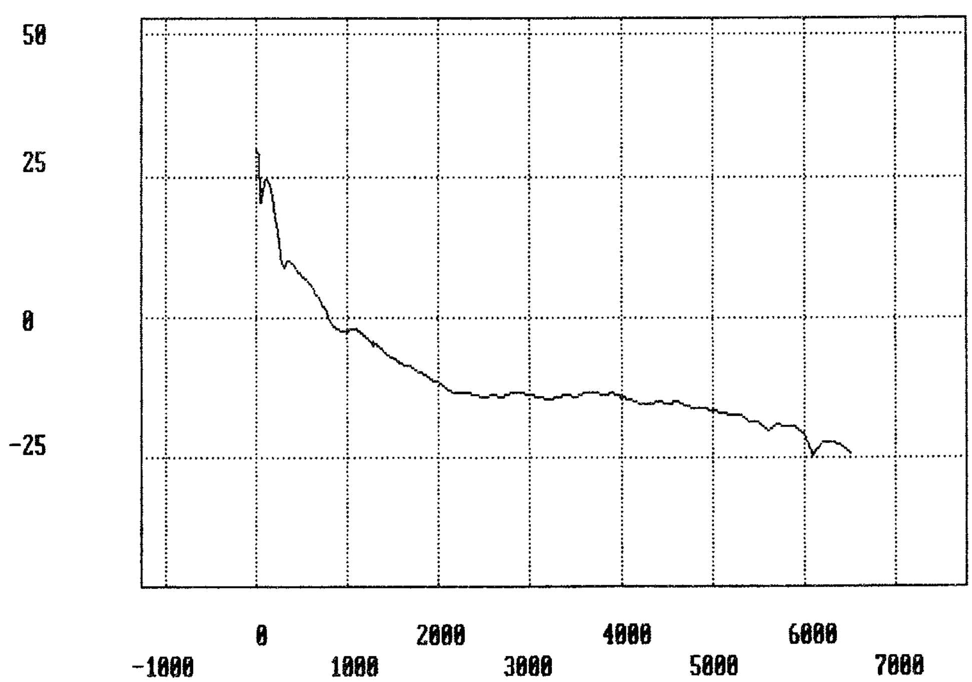
* STA: 177+16.14



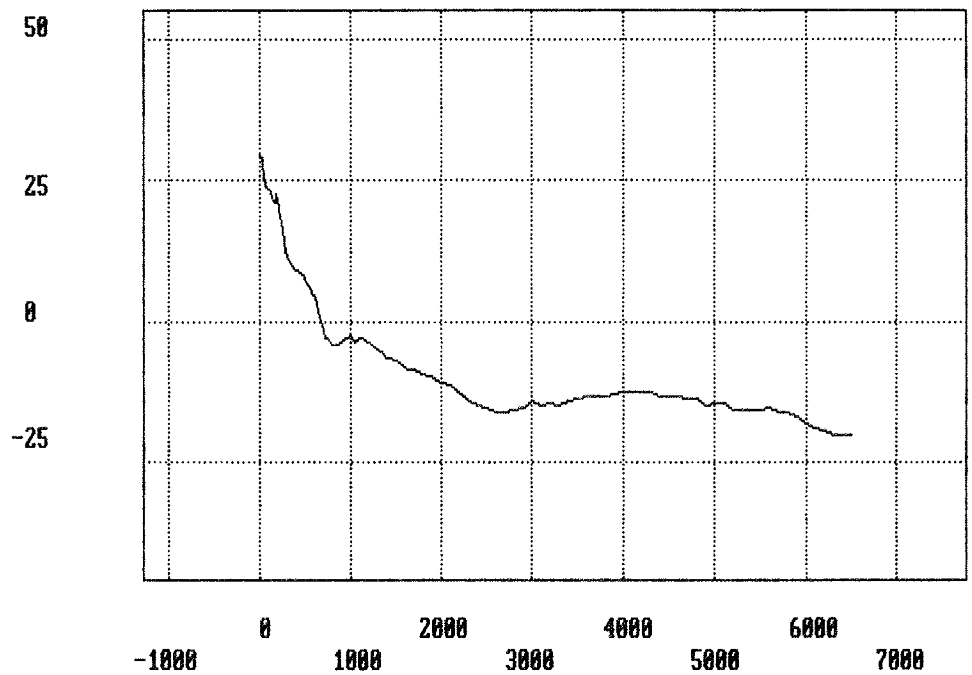
* STA: 179+71.14



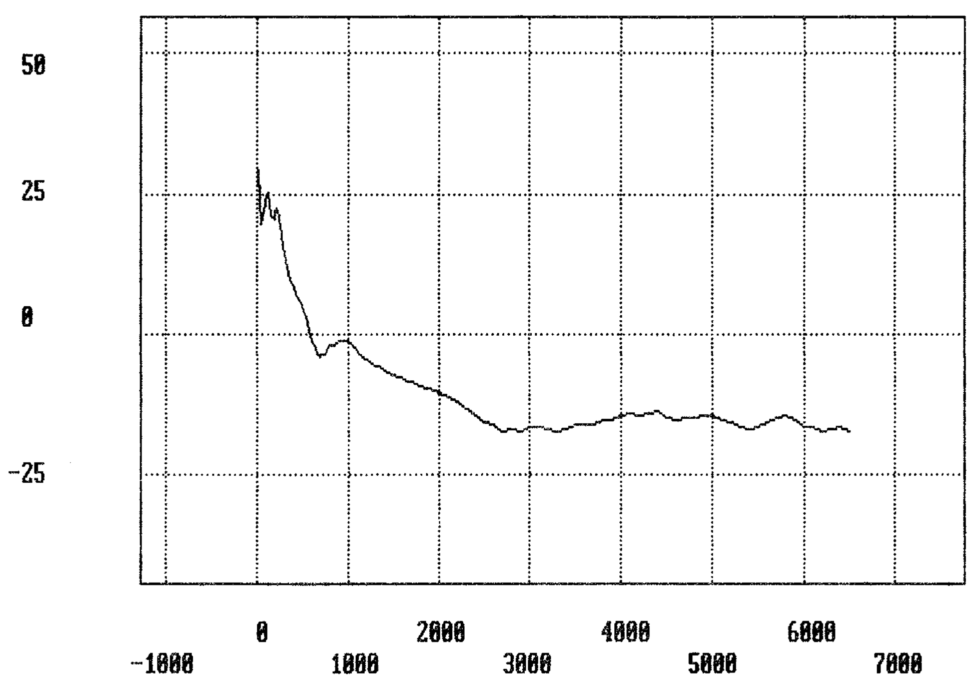
* STA: 183+66.14



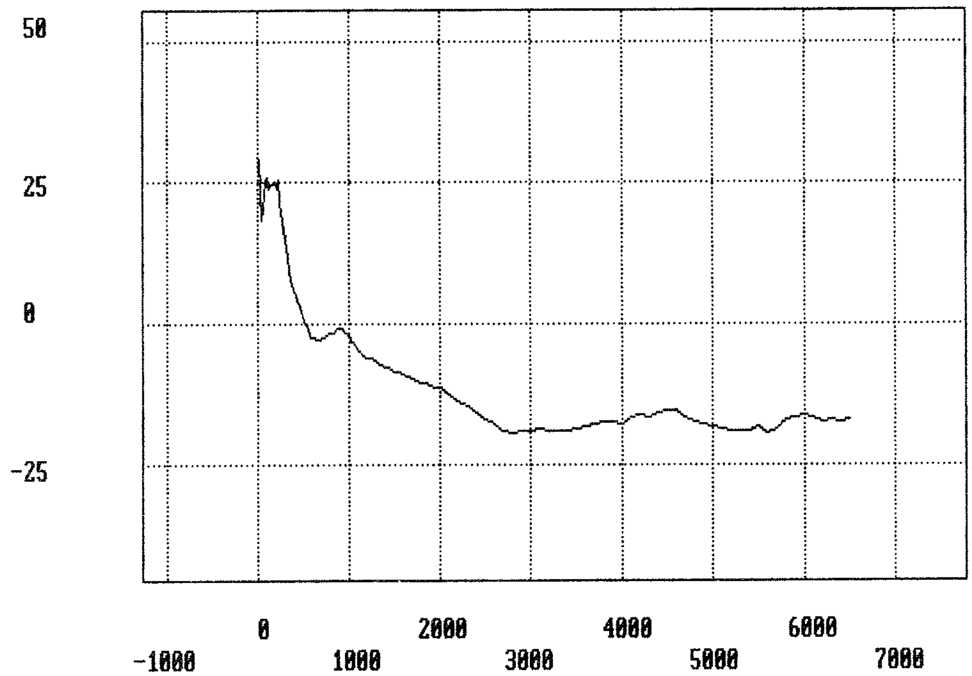
* STA: 188+66.14



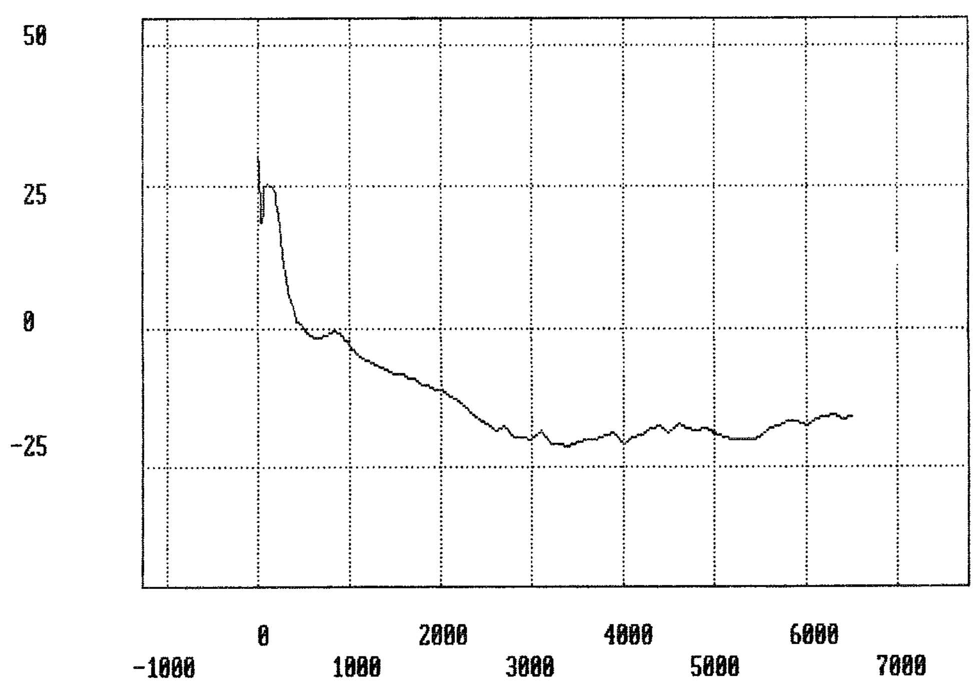
* STA: 193+66.14



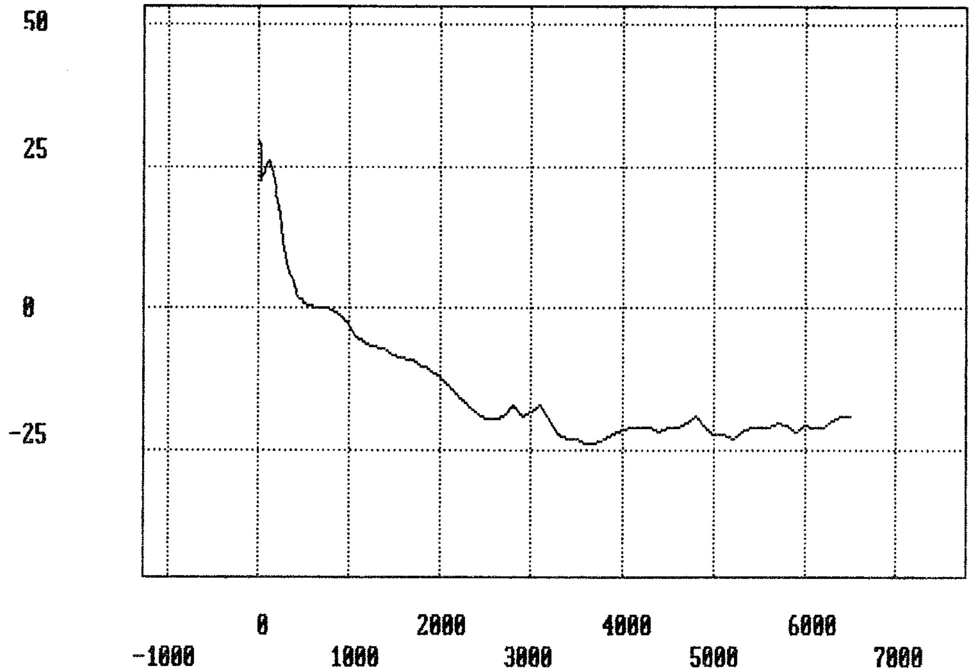
* STA: 198+66.14



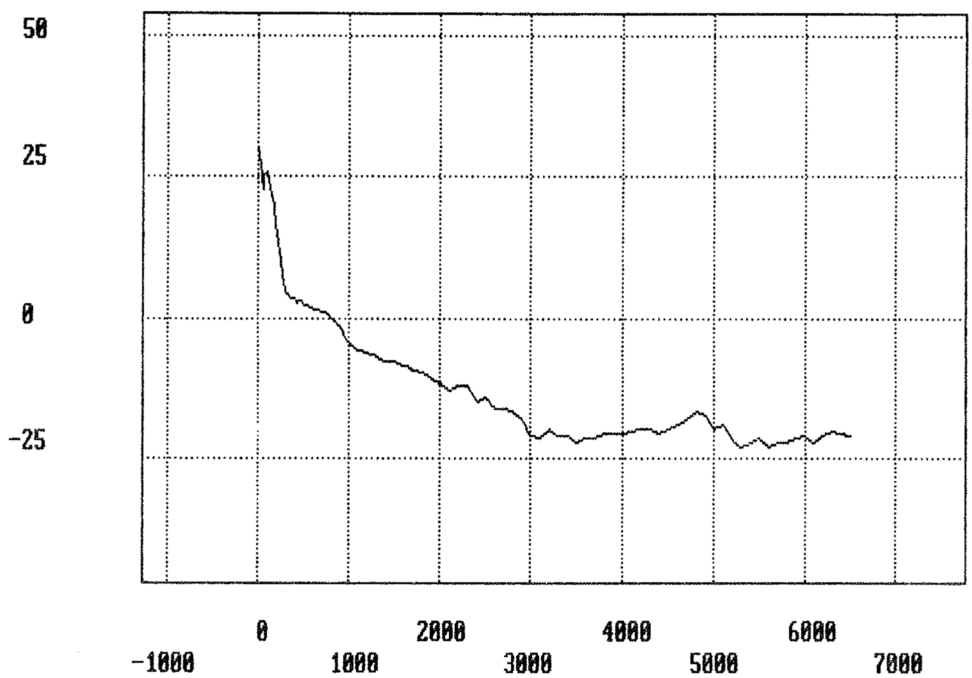
* STA: 204+38.51



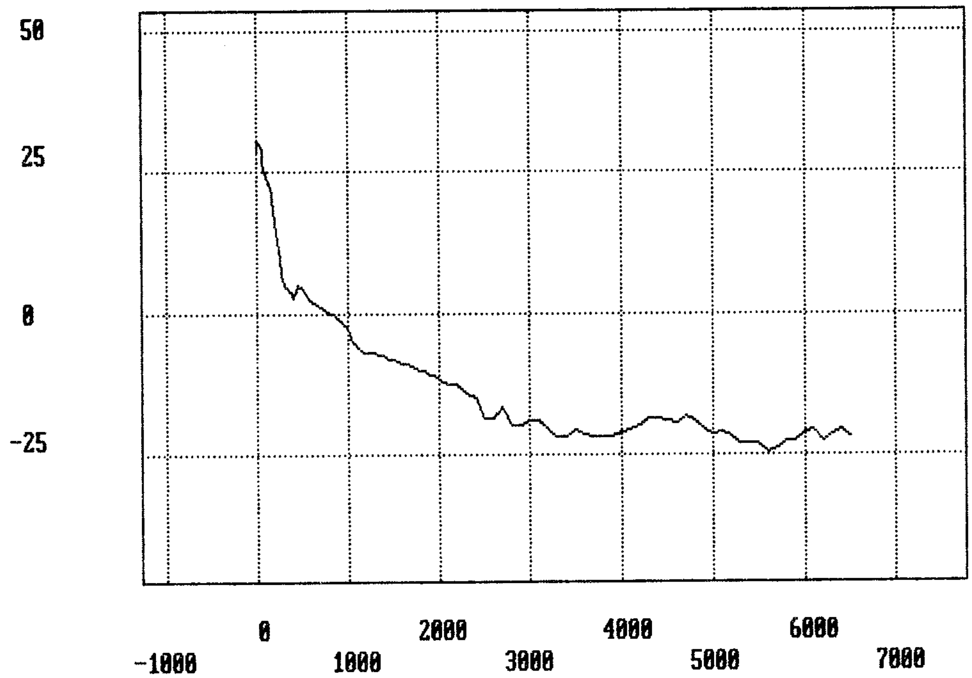
* STA: 215+97.51



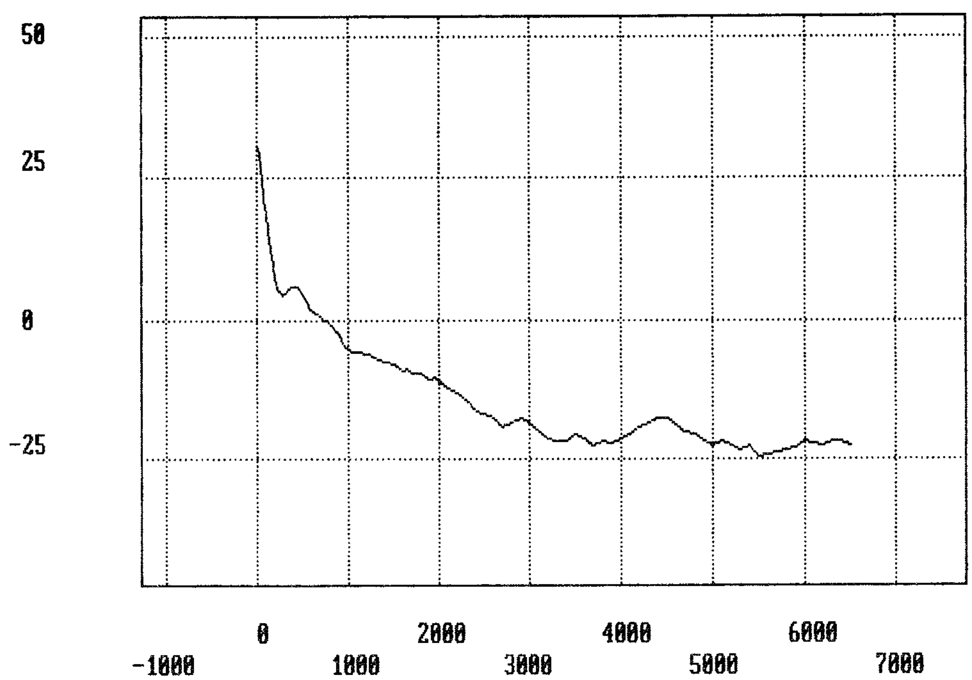
* STA: 227+97.51



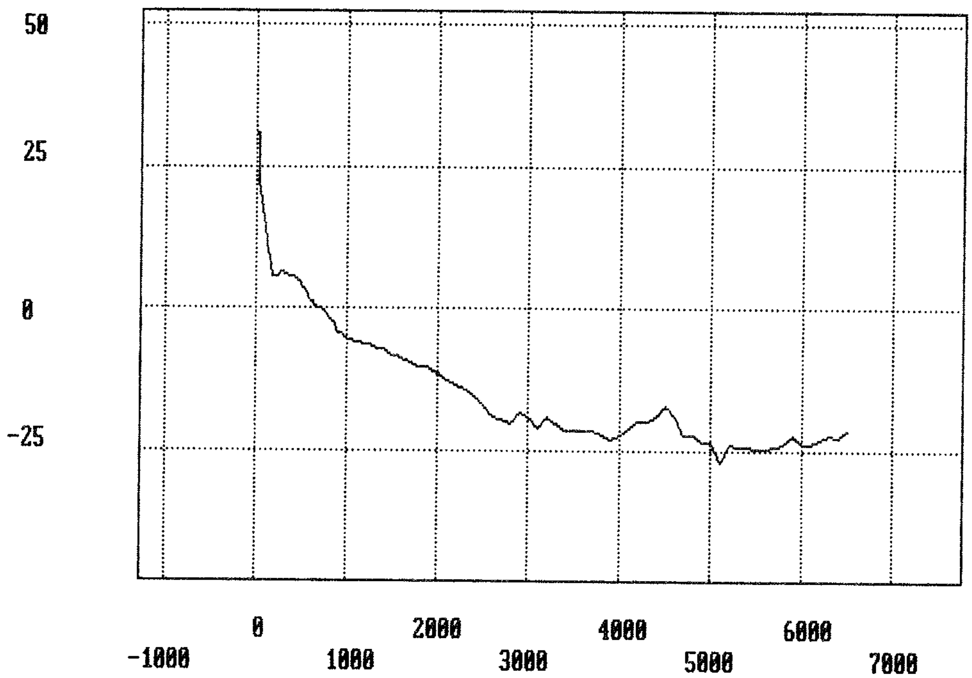
* STA: 234+97.53



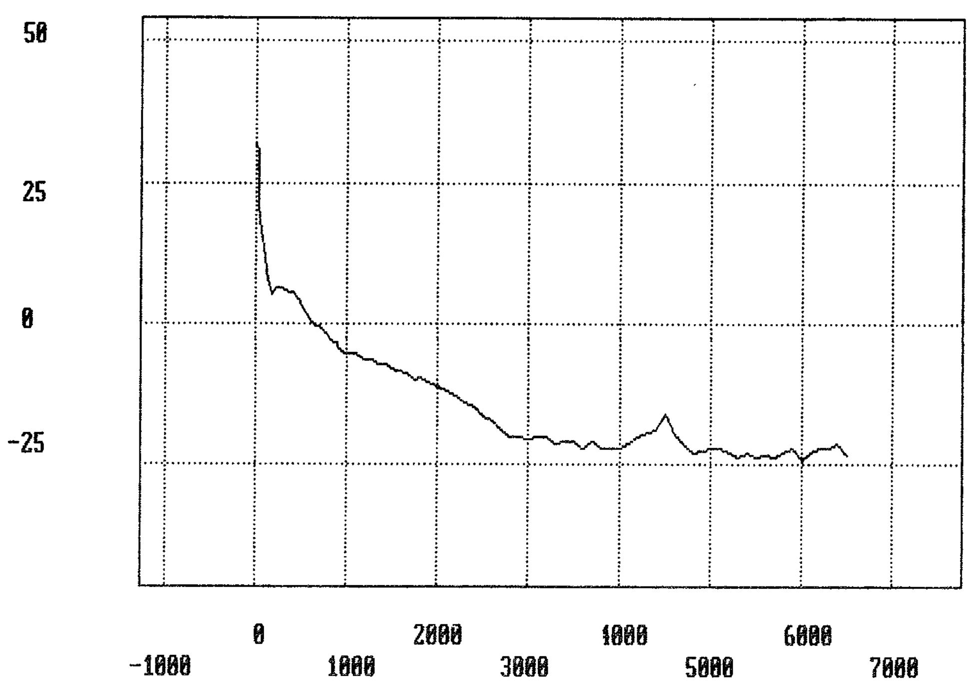
* STA: 239+97.53



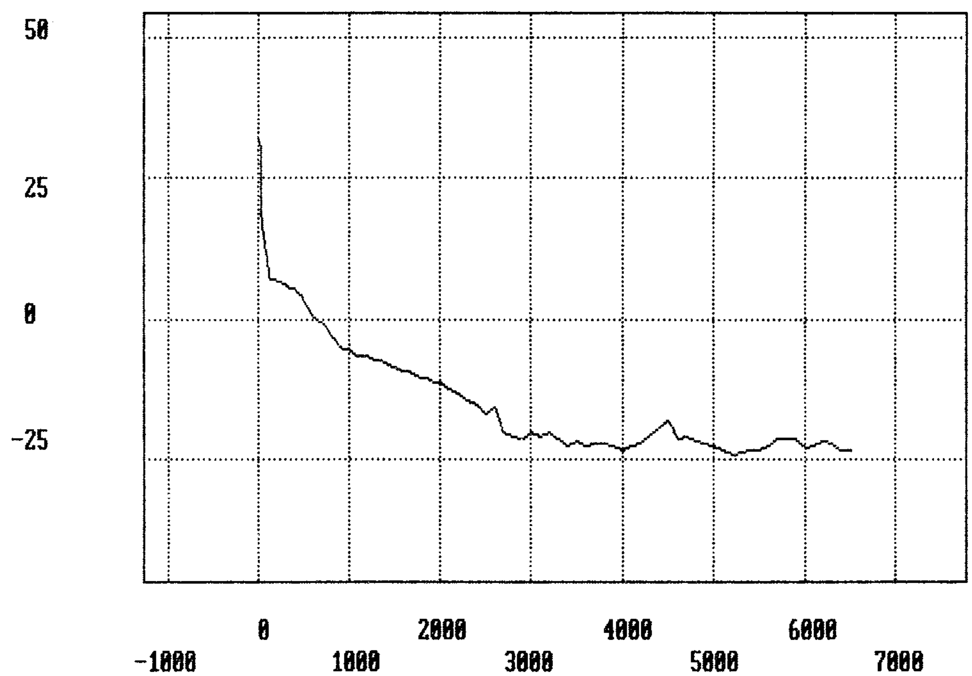
* STA: 242+97.53



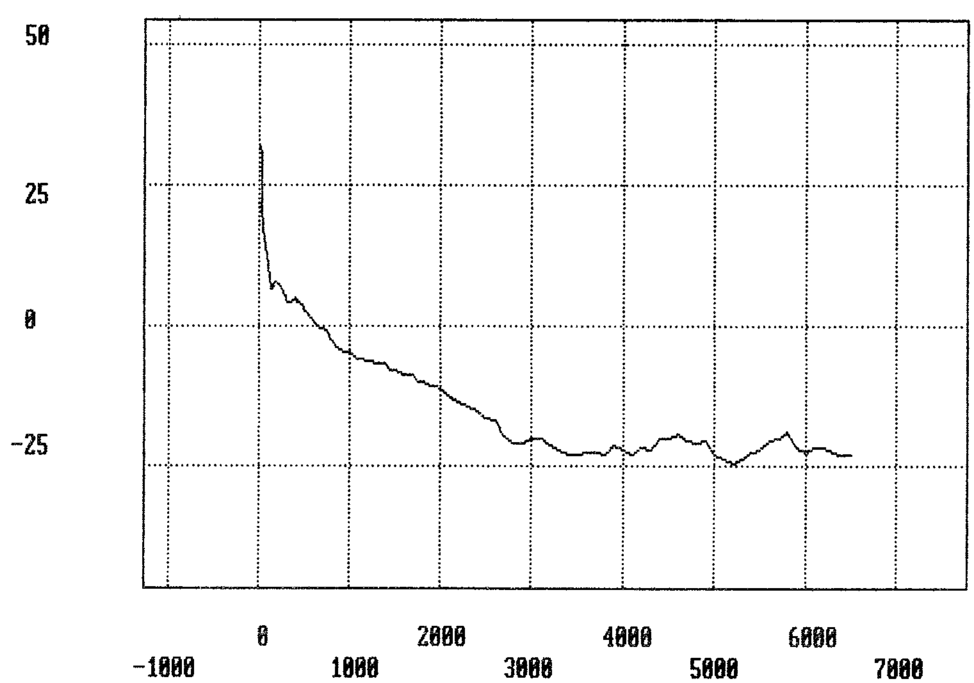
* STA: 244+97.53



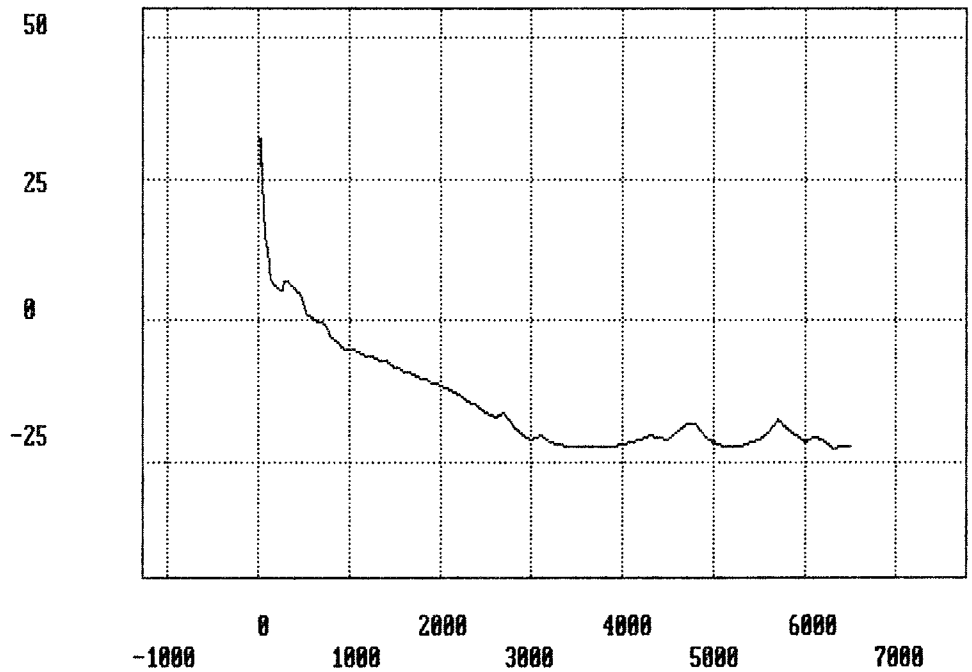
* STA: 246+97.53



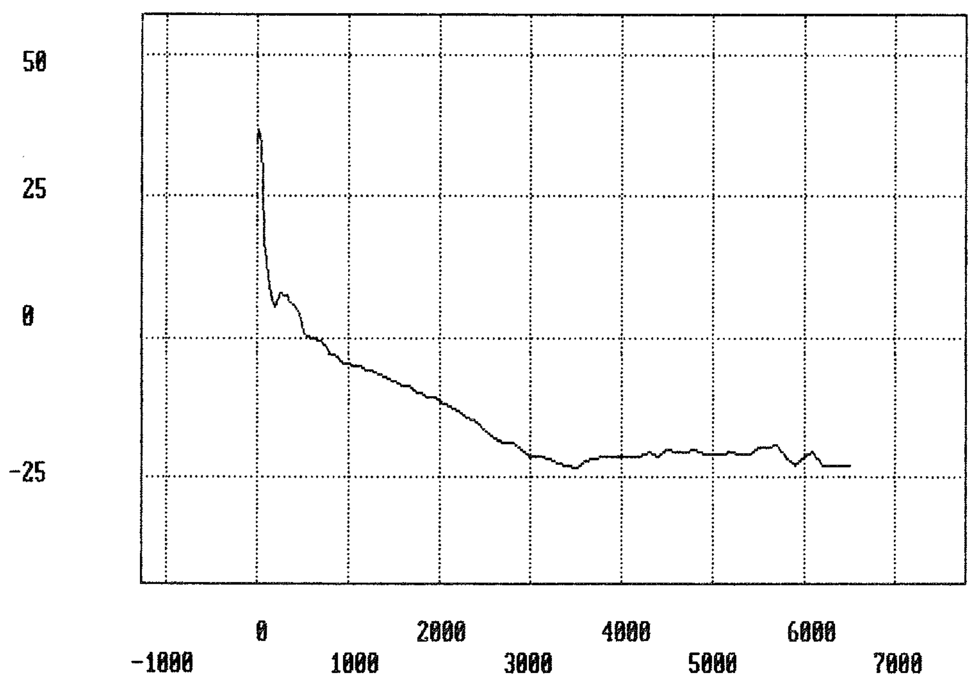
* STA: 248+97.53



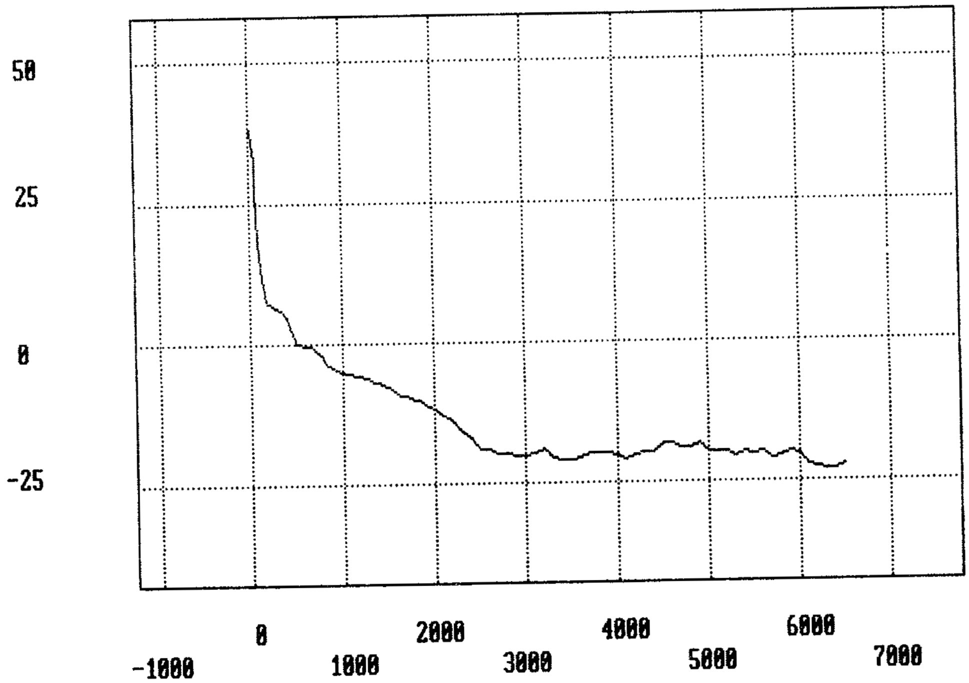
* STA: 250+97.53



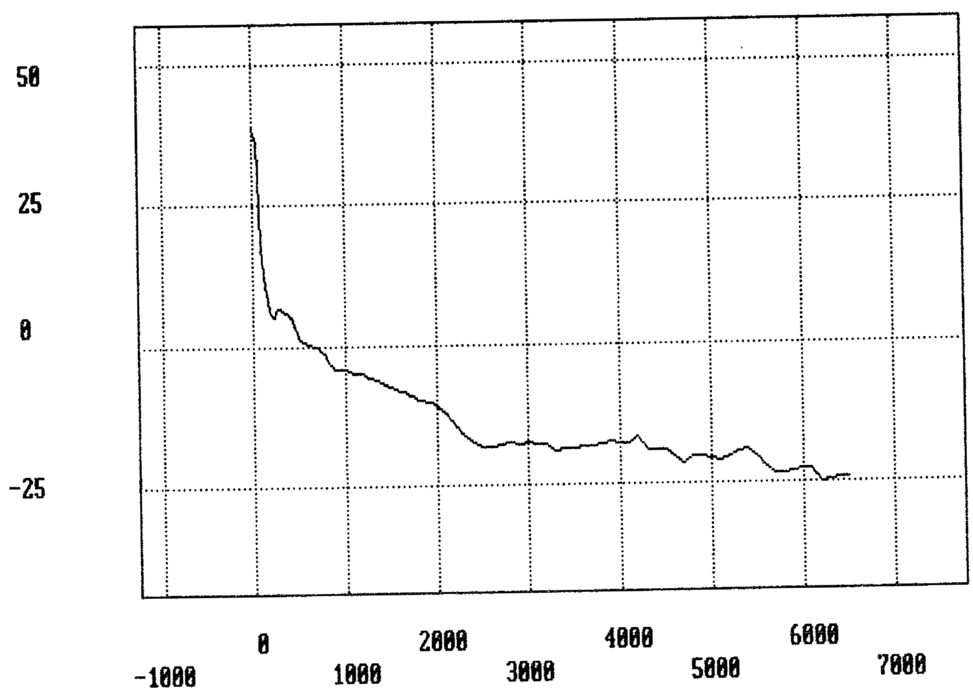
* STA: 253+97.53



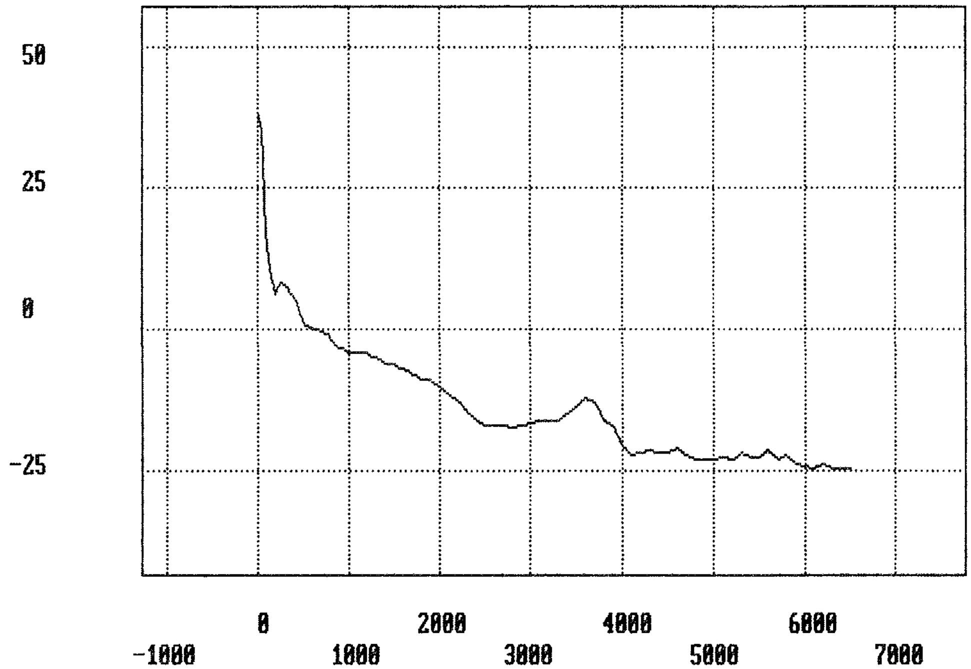
* STA: 258+97.53



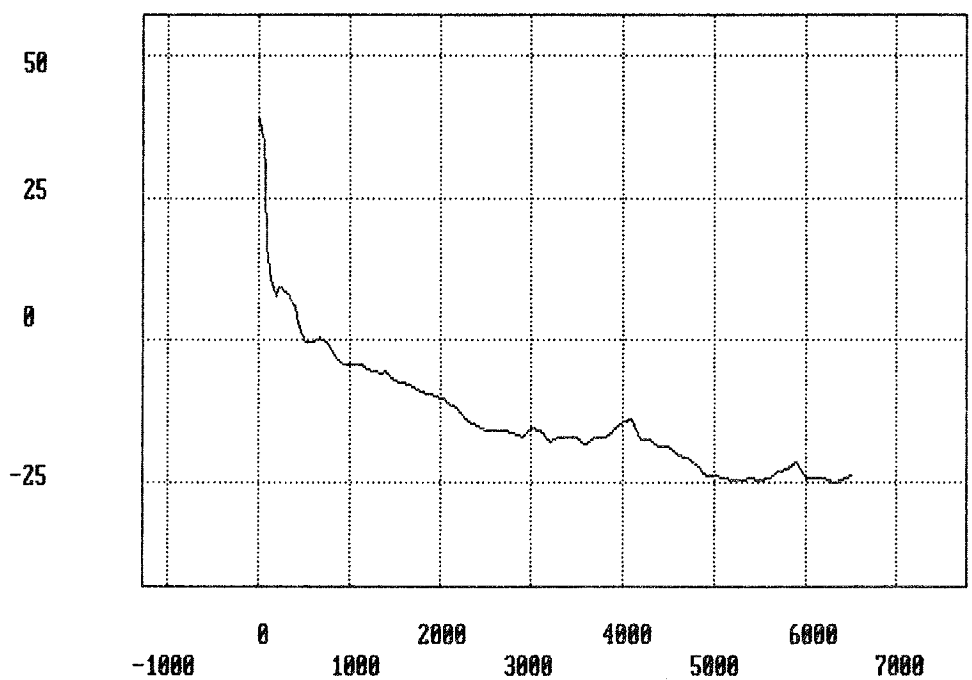
* STA: 263+97.53



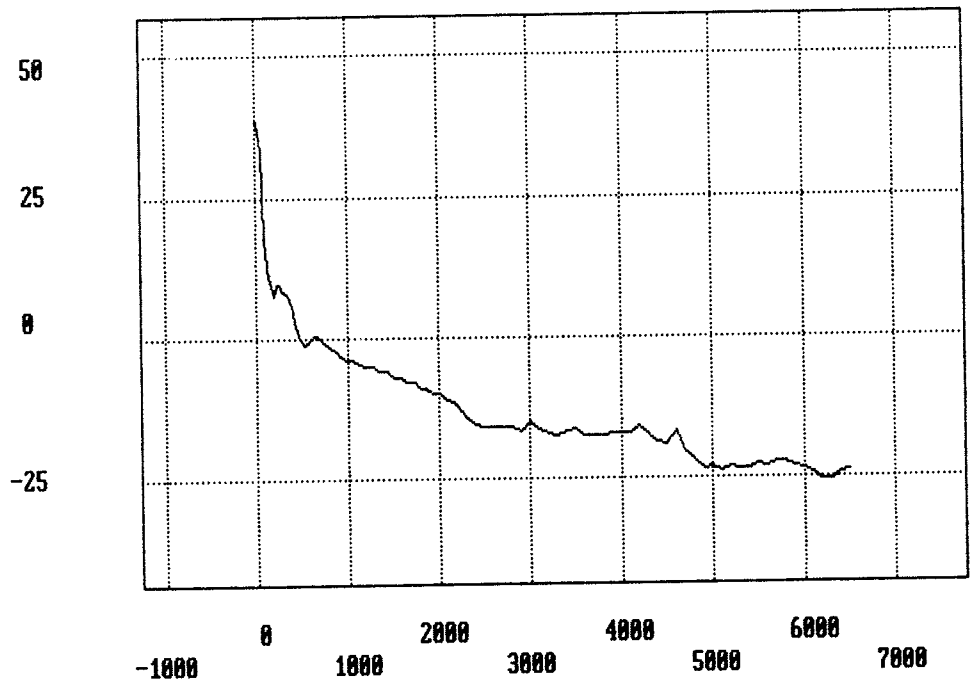
* STA: 268+97.53



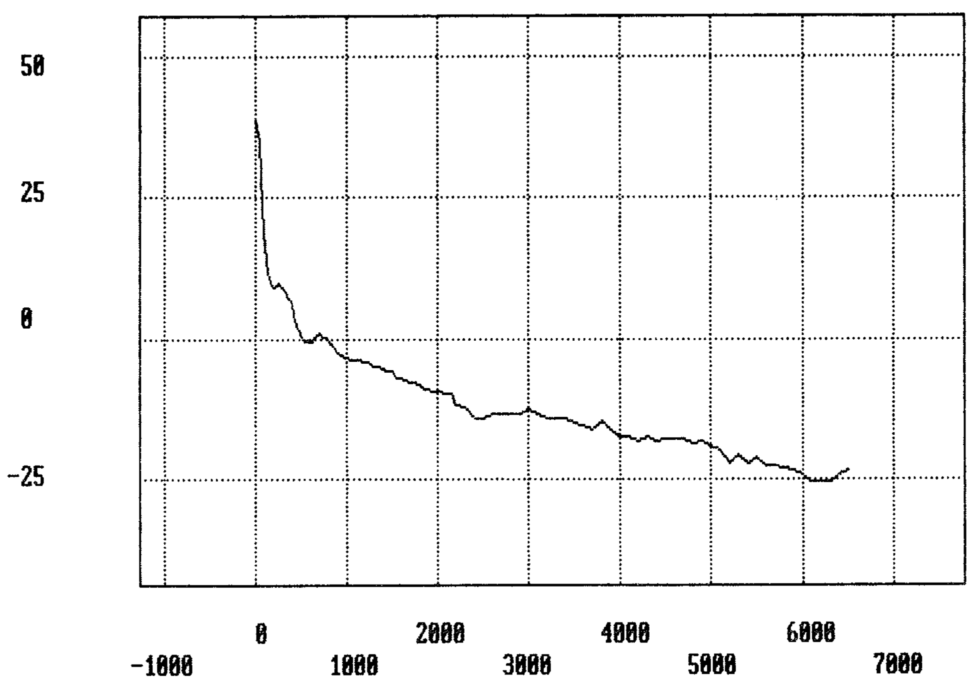
* STA: 273+94.58



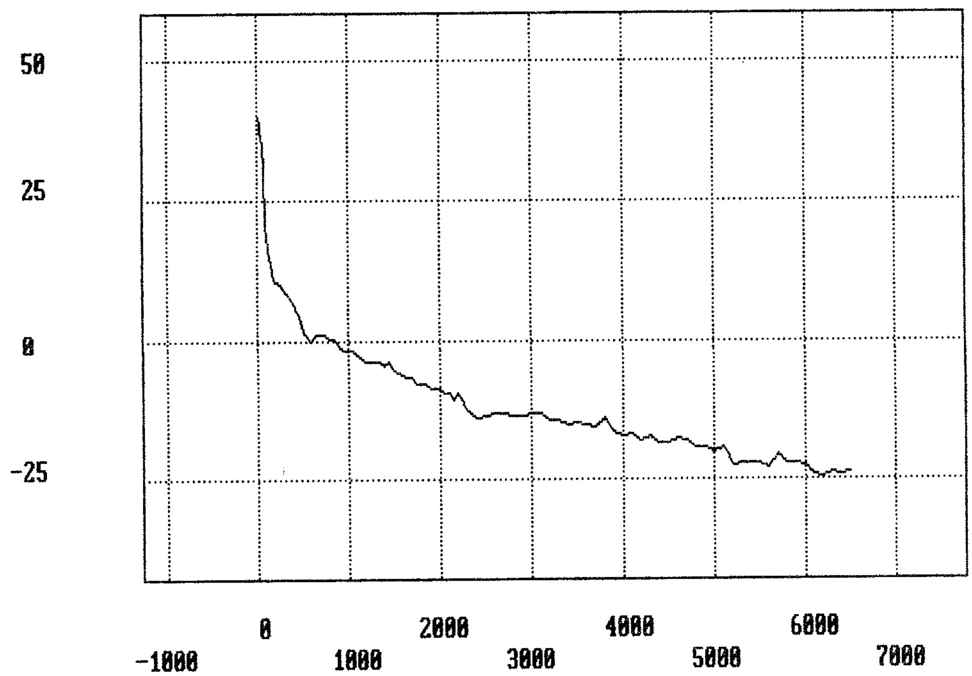
* STA: 275+86.22



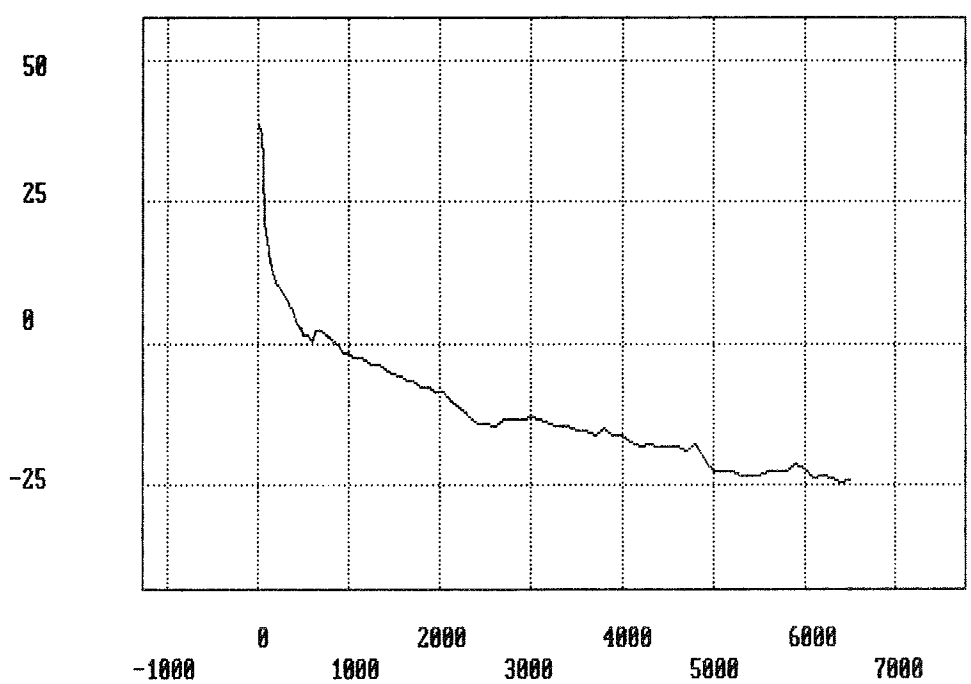
* STA: 279+86.22

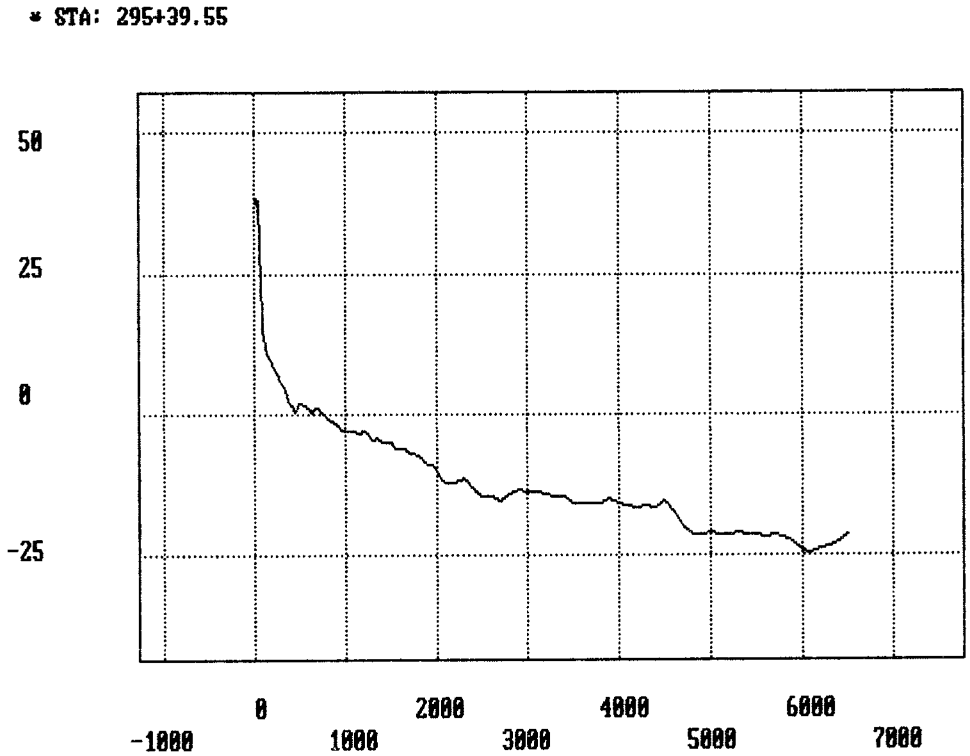


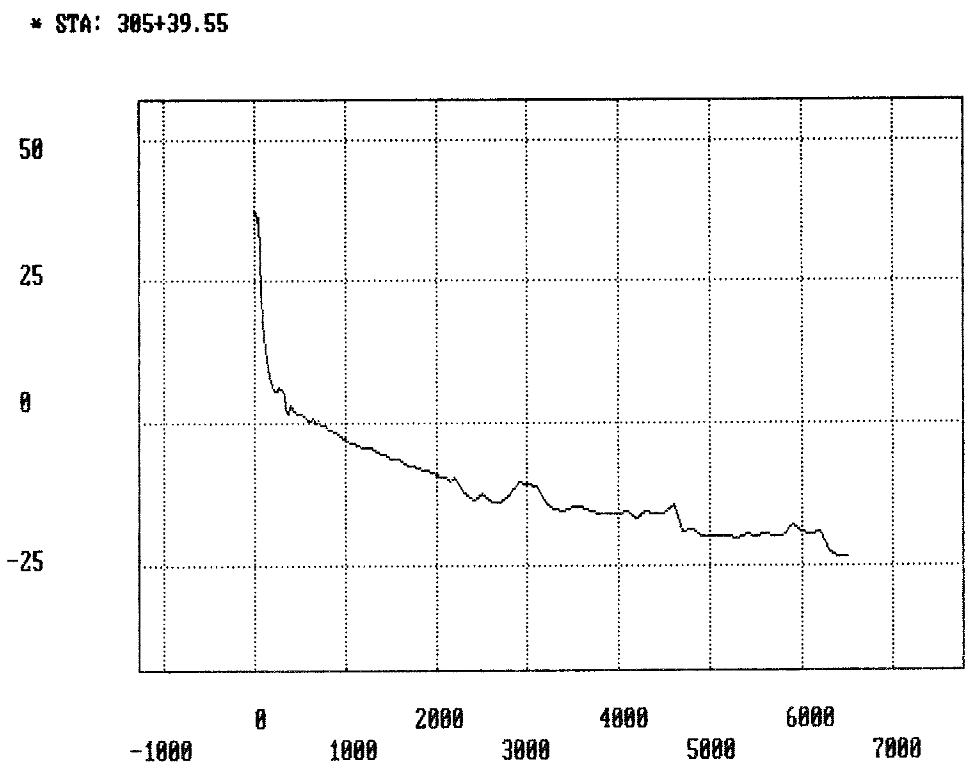
* STA: 283+59.31



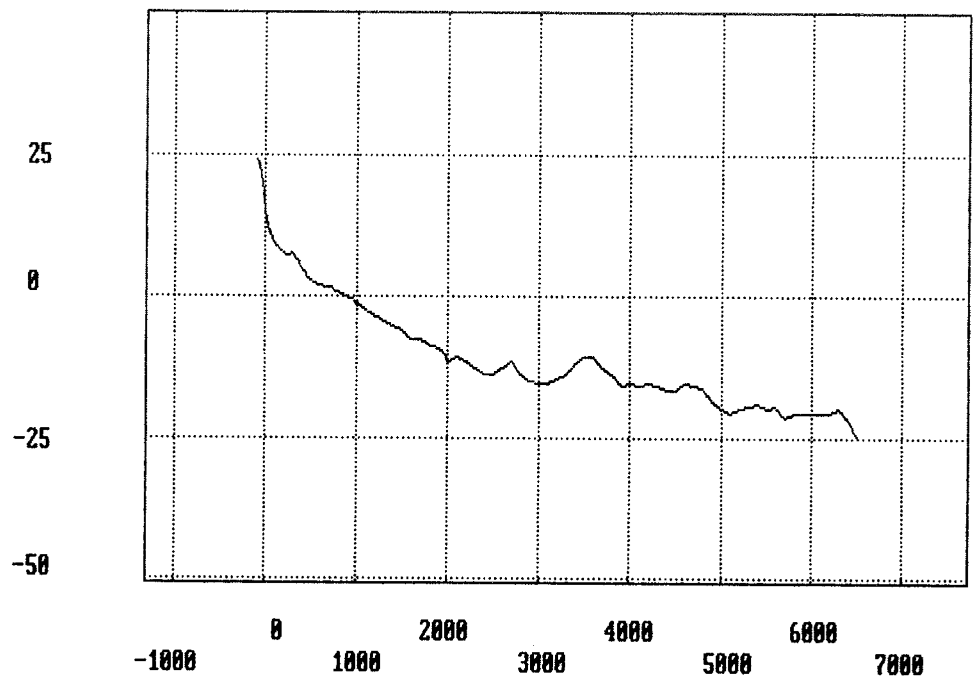
* STA: 288+89.55




* STA: 295+39.55
50
25
0
-25
0
2000
4000
6000
-1000
1000
3000
5000
7000


* STA: 305+39.55
50
25
0
-25
0
2000
4000
6000
-1000
1000
3000
5000
7000

* STA: 315+39.56



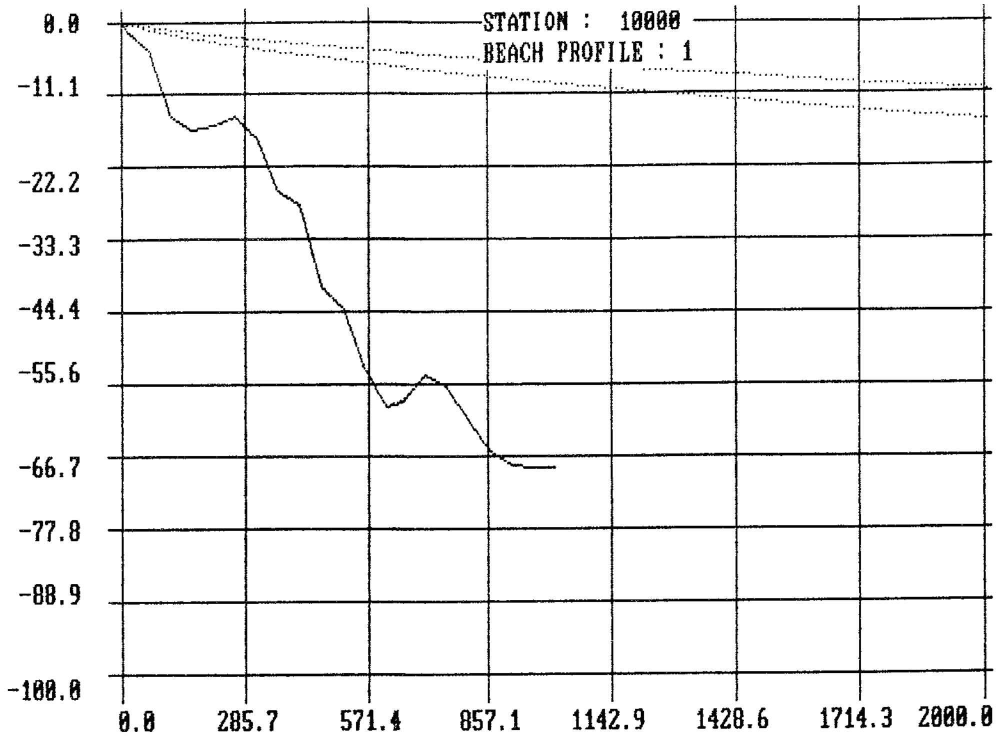
APPENDIX D: Supplement 2

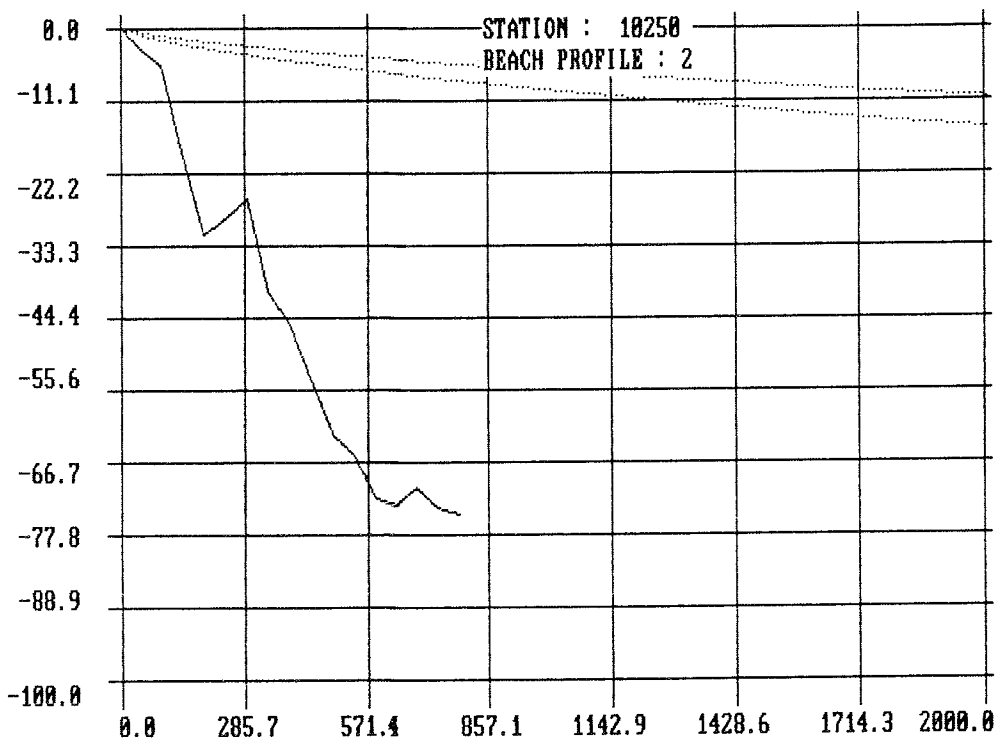
HOMER SPIT, ALASKA

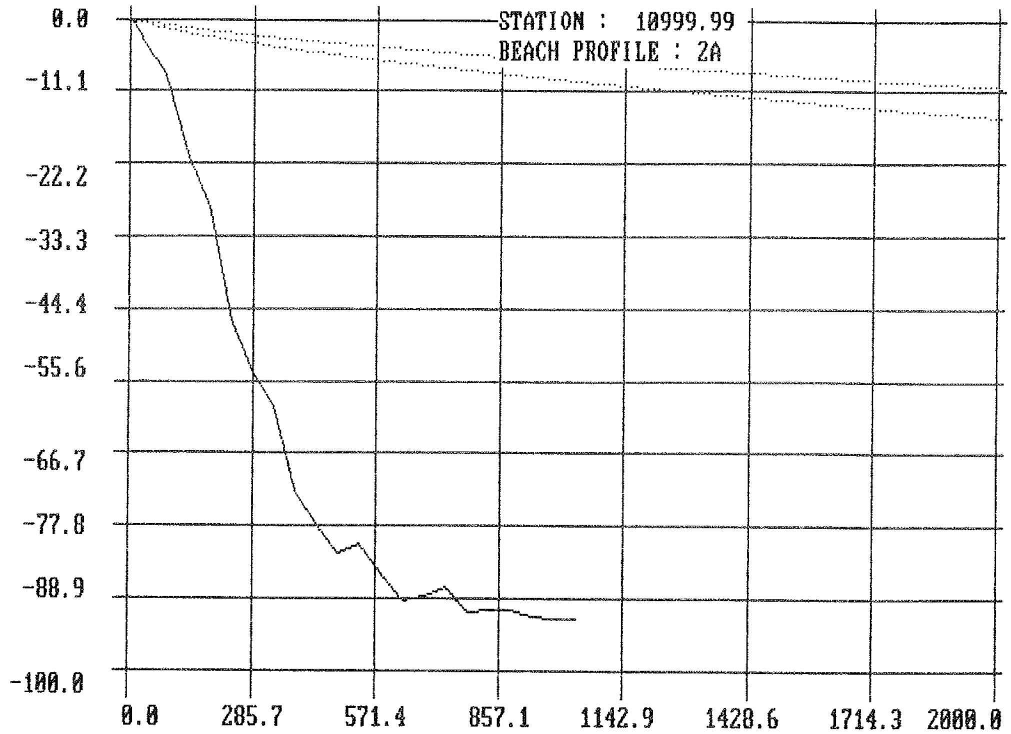
BEACH PROFILES

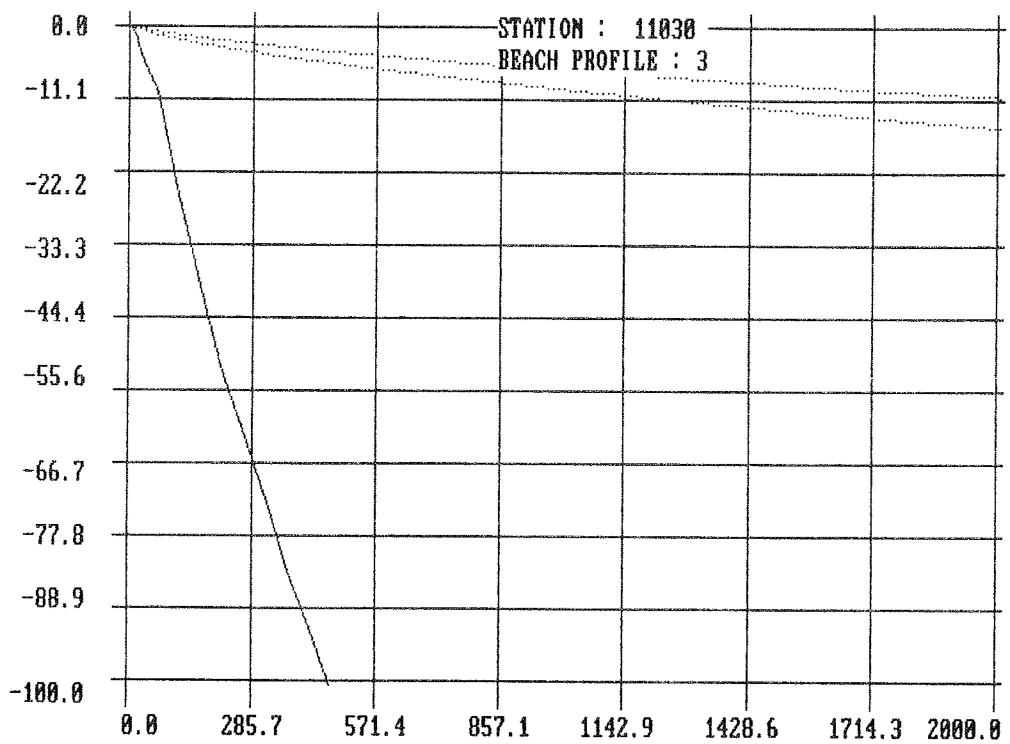
UPPER DOTTED LINE Y = -.07*X^2/3
LOWER DOTTED LINE Y = -.10*X^2/3
SOLID LINE FROM ACTUAL PROFILE DATA

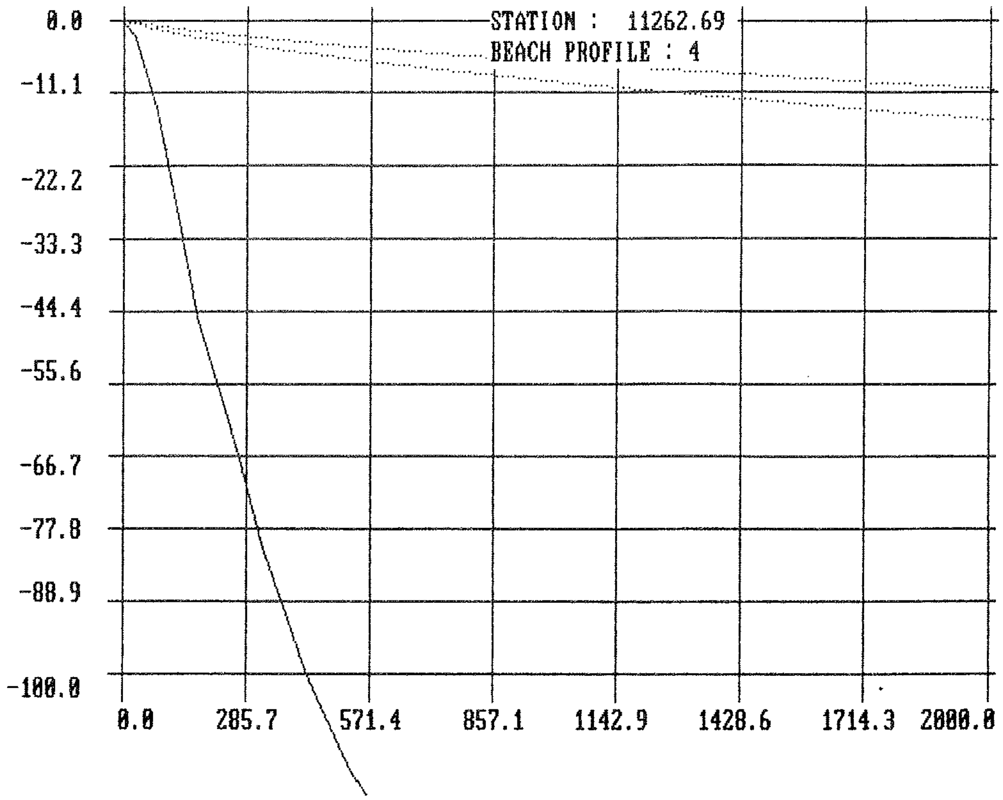
BEACH PROFILES	1-19,21	(2000 X 100)
BEACH PROFILES	20,22-23	(4000 X 100)
BEACH PROFILES	24-32	(4000 X 50)
BEACH PROFILES	33-60	(4000 X 50)


STATION : 10000
BEACH PROFILE : 1
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0

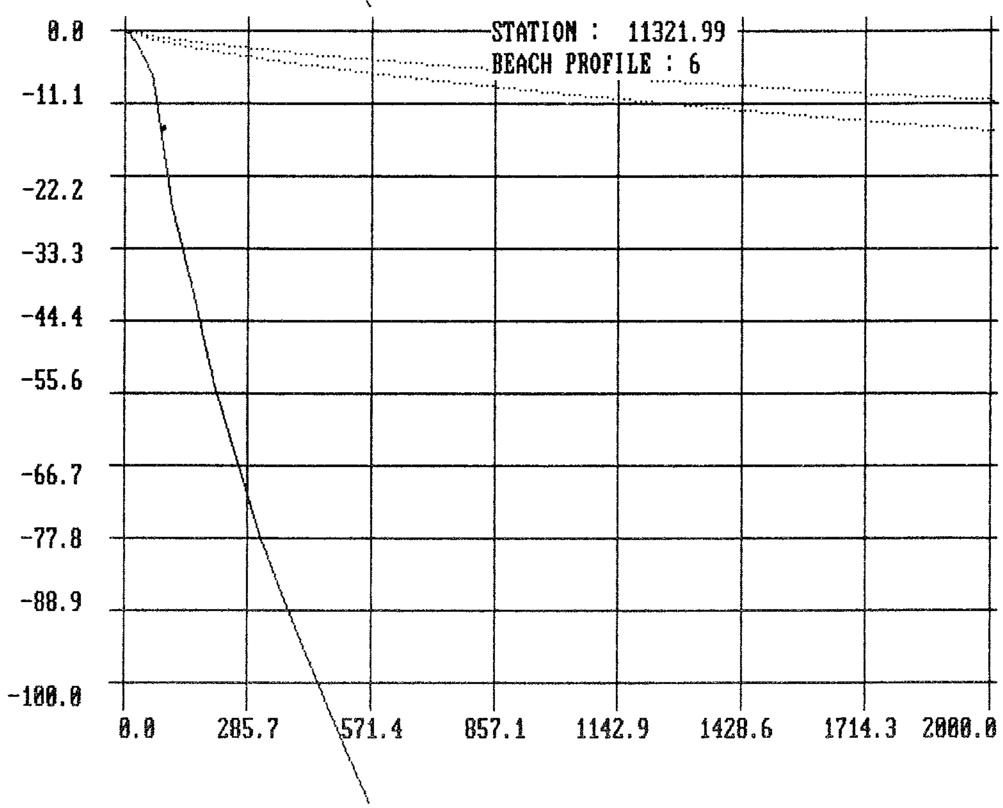

STATION : 10250
BEACH PROFILE : 2
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 10999.99
BEACH PROFILE : 2A
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0

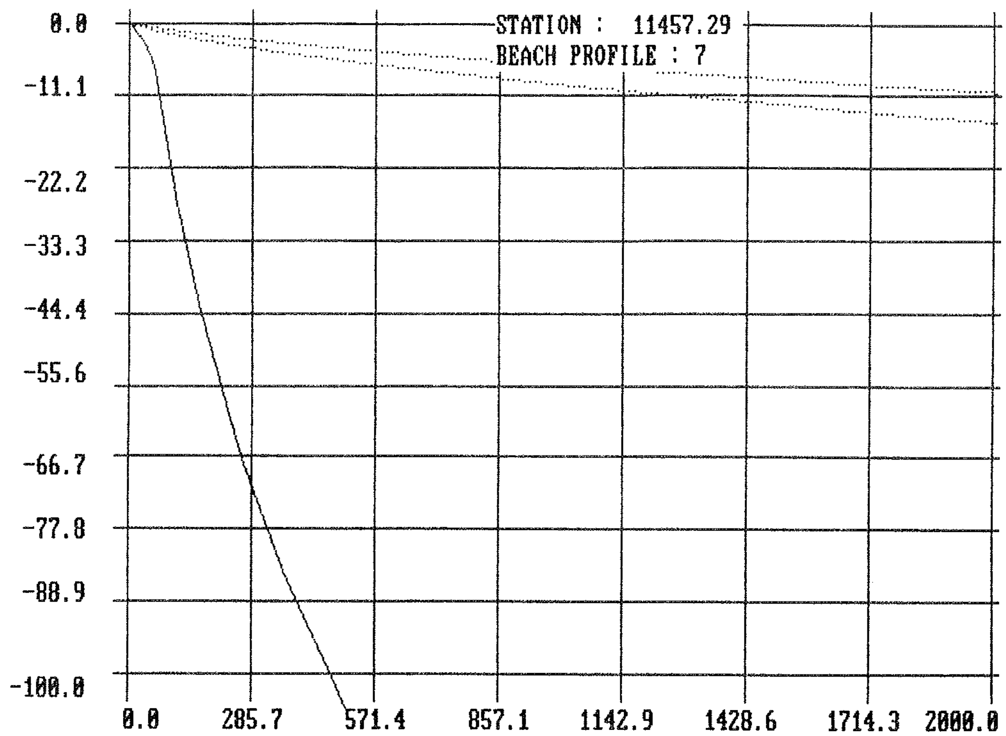

STATION : 11030
BEACH PROFILE : 3
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0

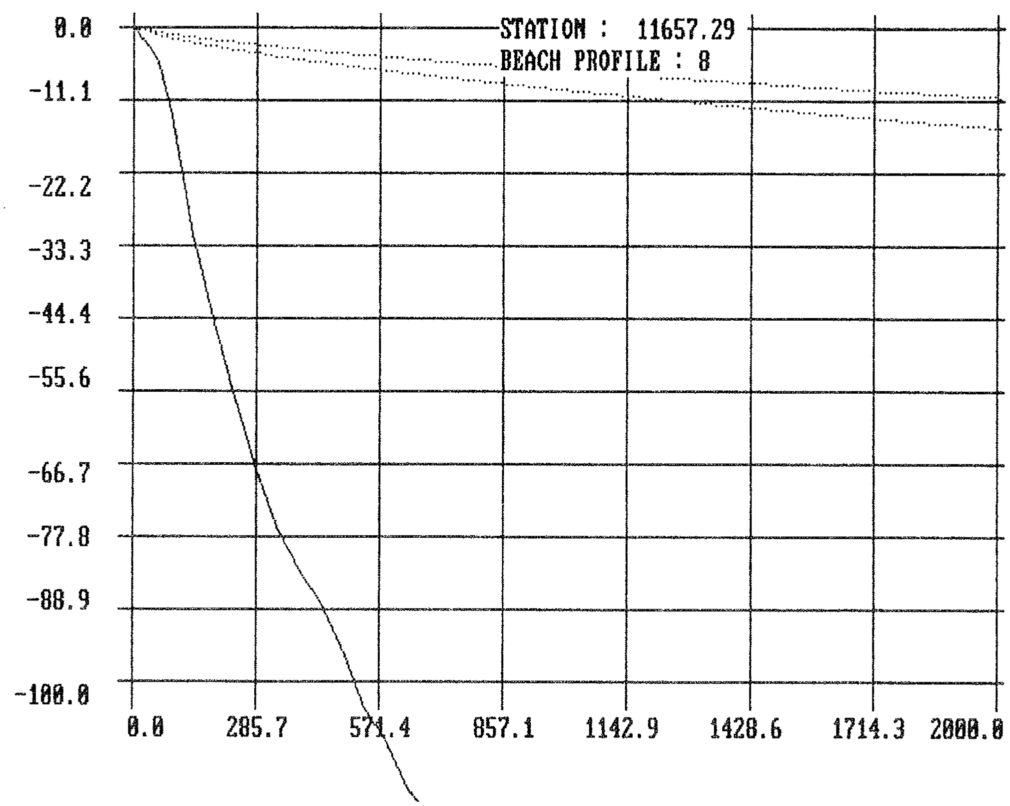


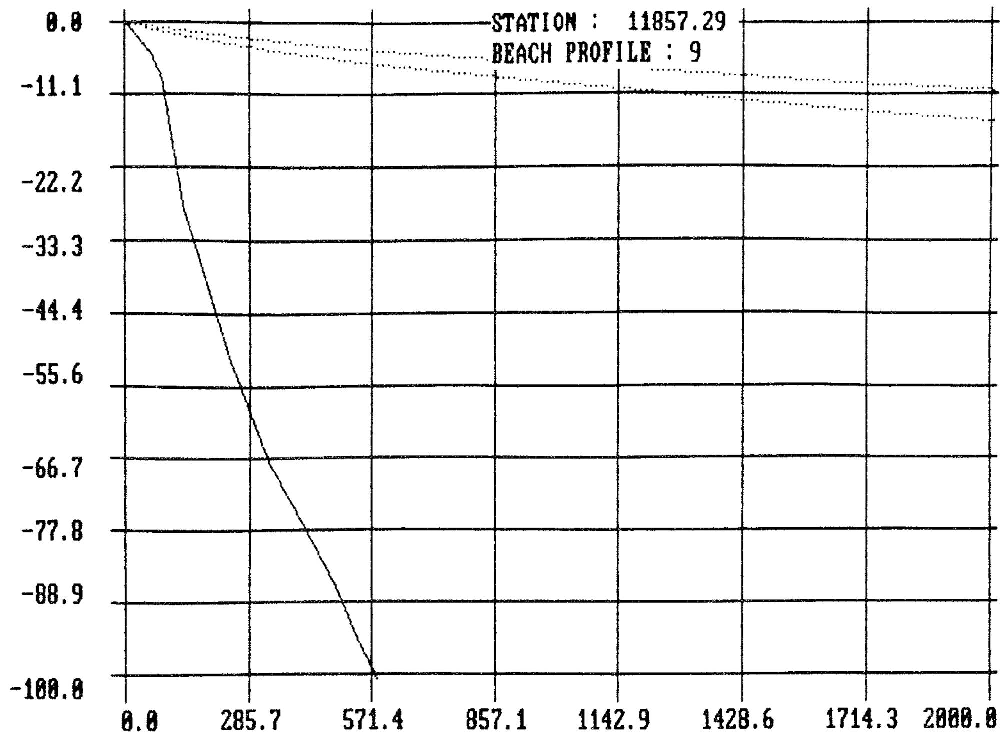
STATION : 11262.69
BEACH PROFILE : 4
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0

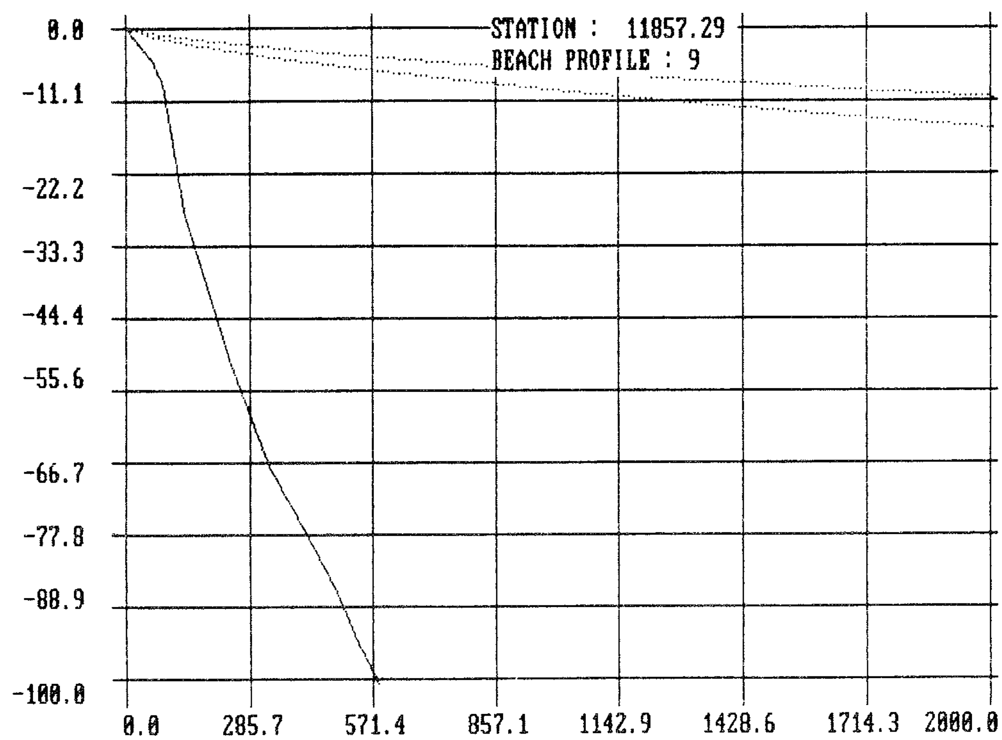


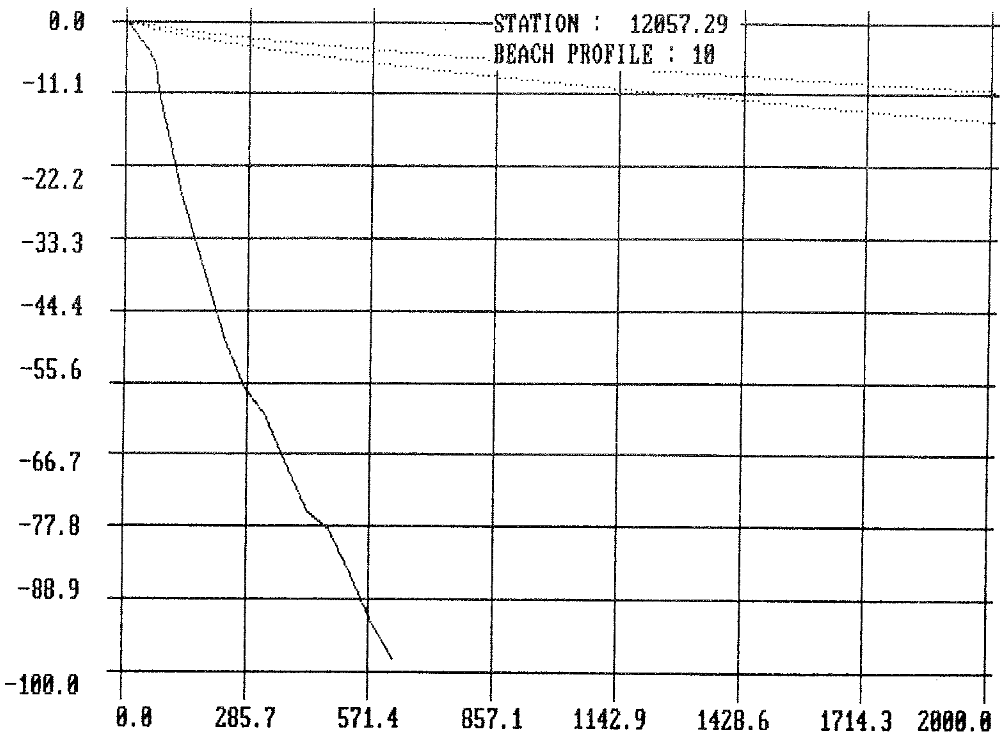
STATION : 11321.99
BEACH PROFILE : 6
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 11457.29
BEACH PROFILE : 7
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 11657.29
BEACH PROFILE : 8
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 11857.29
BEACH PROFILE : 9
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 11857.29
BEACH PROFILE : 9
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 12057.29
BEACH PROFILE : 10
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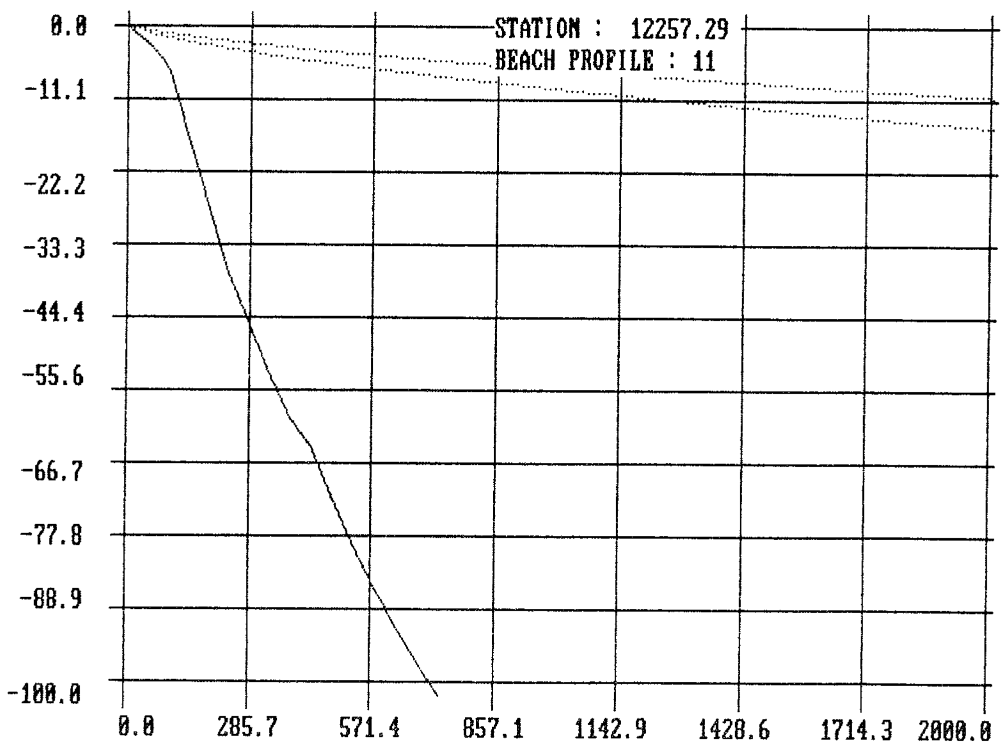
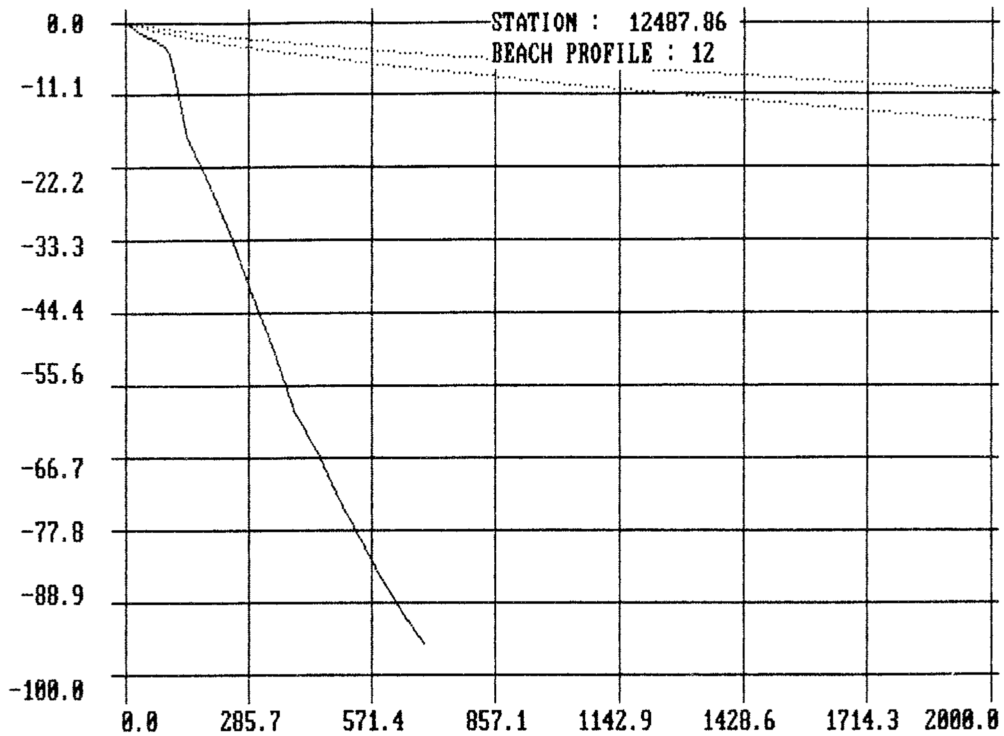
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 12257.29
BEACH PROFILE : 11
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 12487.86
BEACH PROFILE : 12
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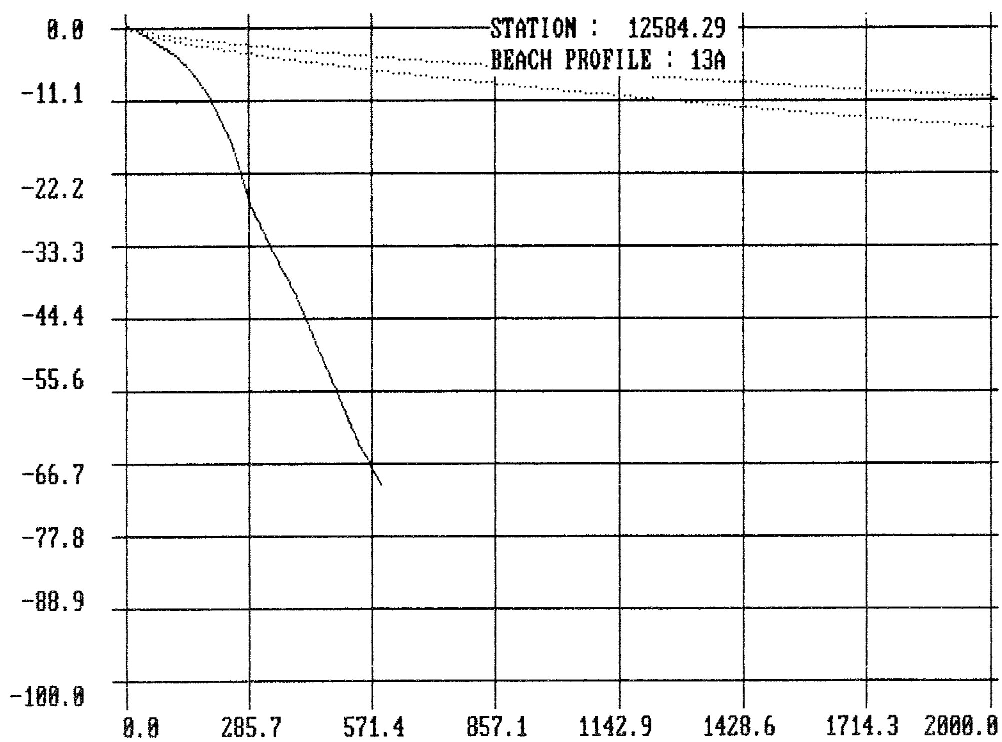
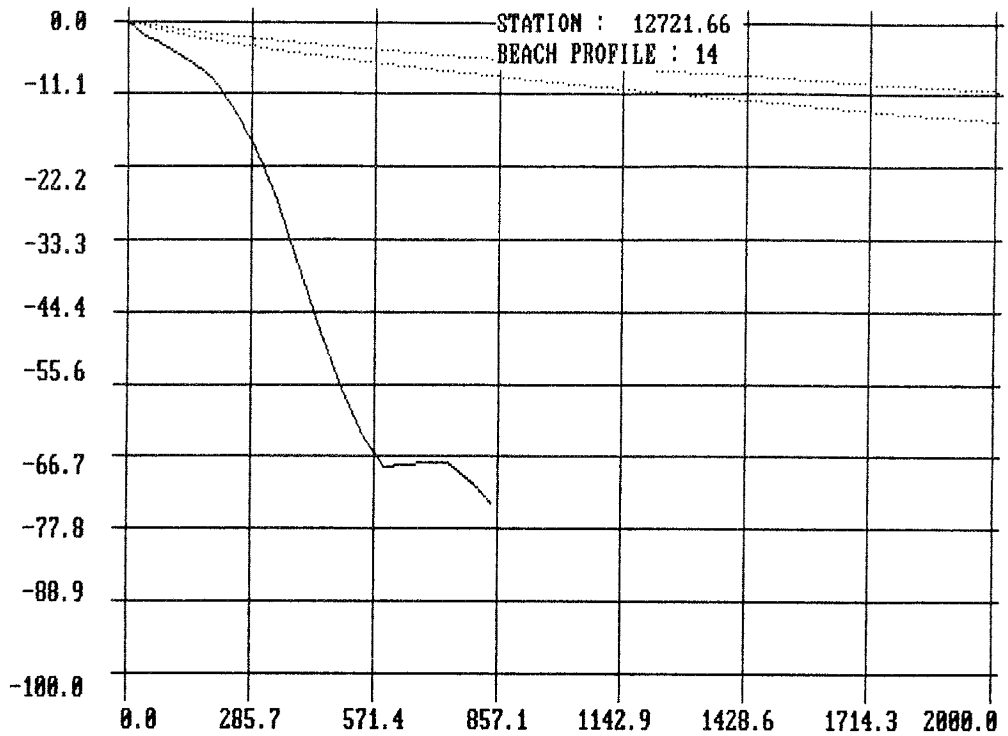
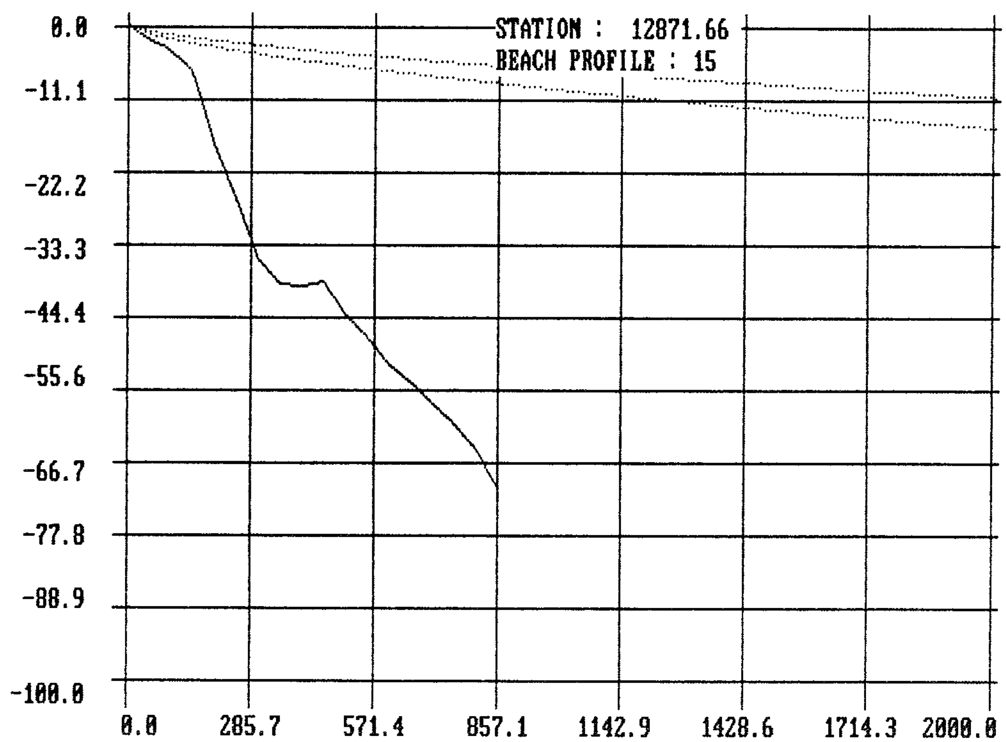
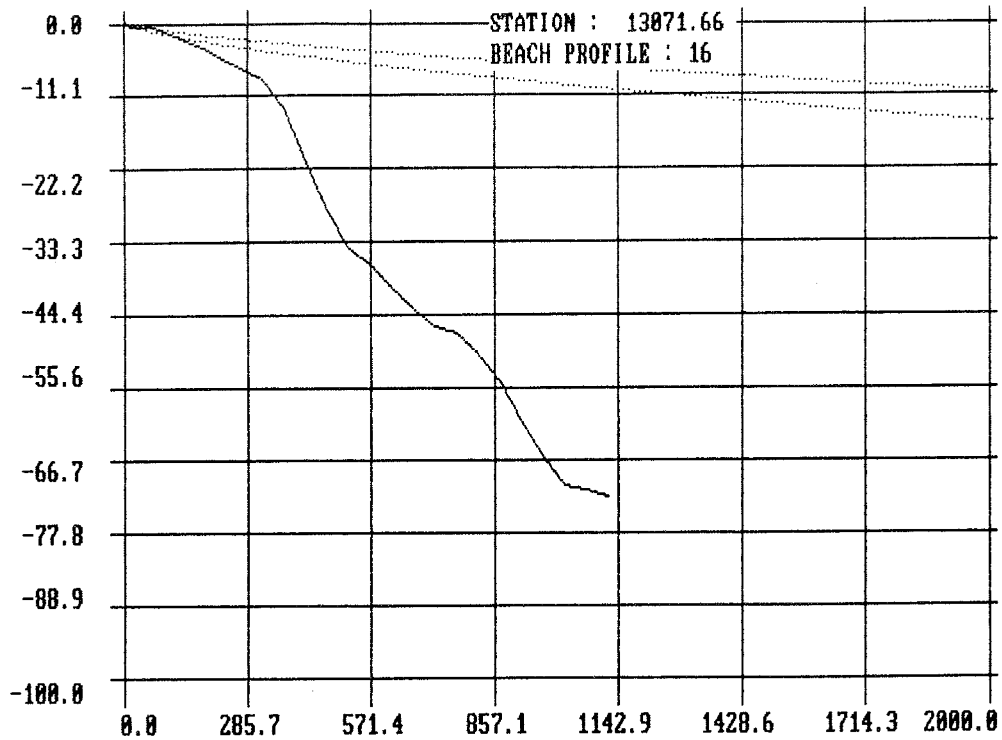
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 12584.29
BEACH PROFILE : 13A
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 12721.66
BEACH PROFILE : 14
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 12871.66
BEACH PROFILE : 15
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 13071.66
BEACH PROFILE : 16
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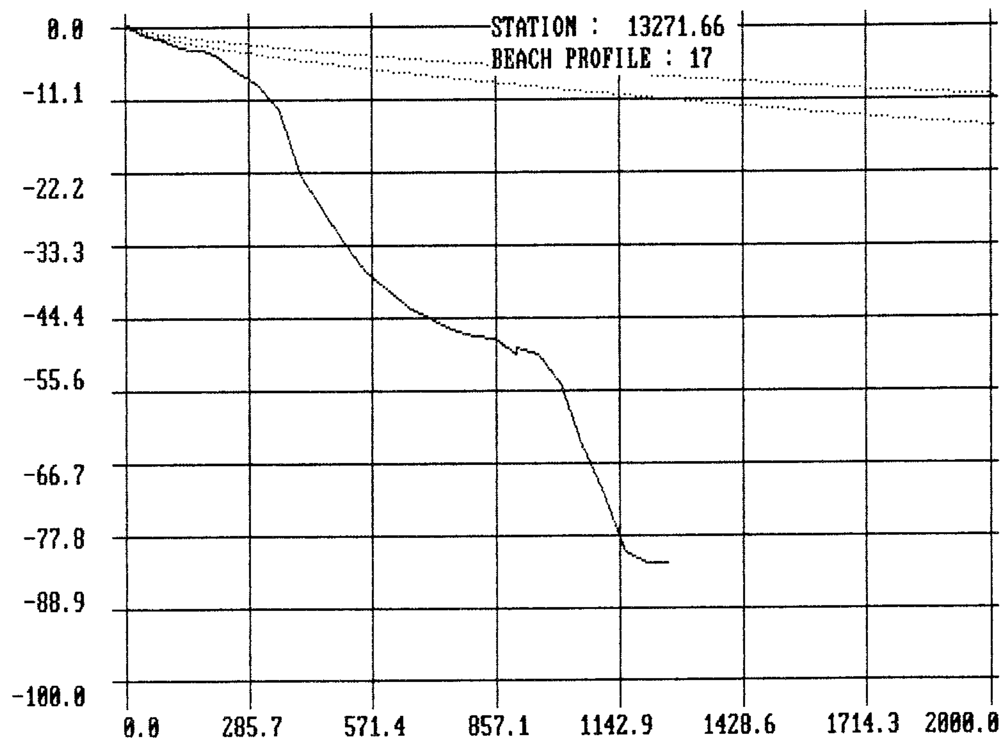
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 13271.66
BEACH PROFILE : 17
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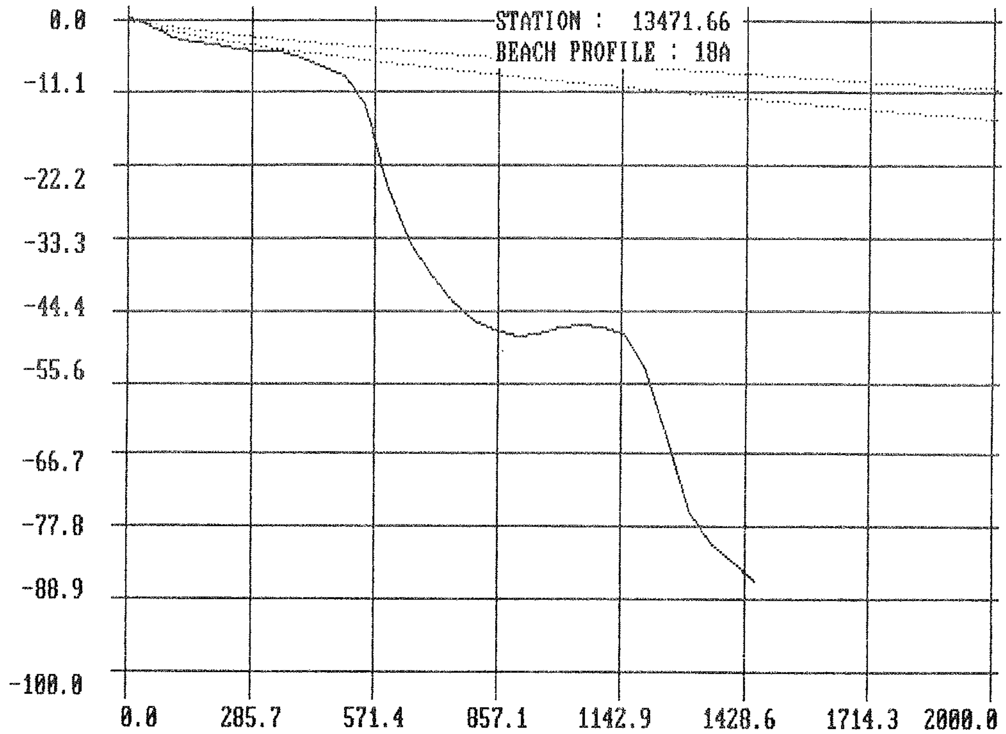
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 13471.66
BEACH PROFILE : 18A
0.0
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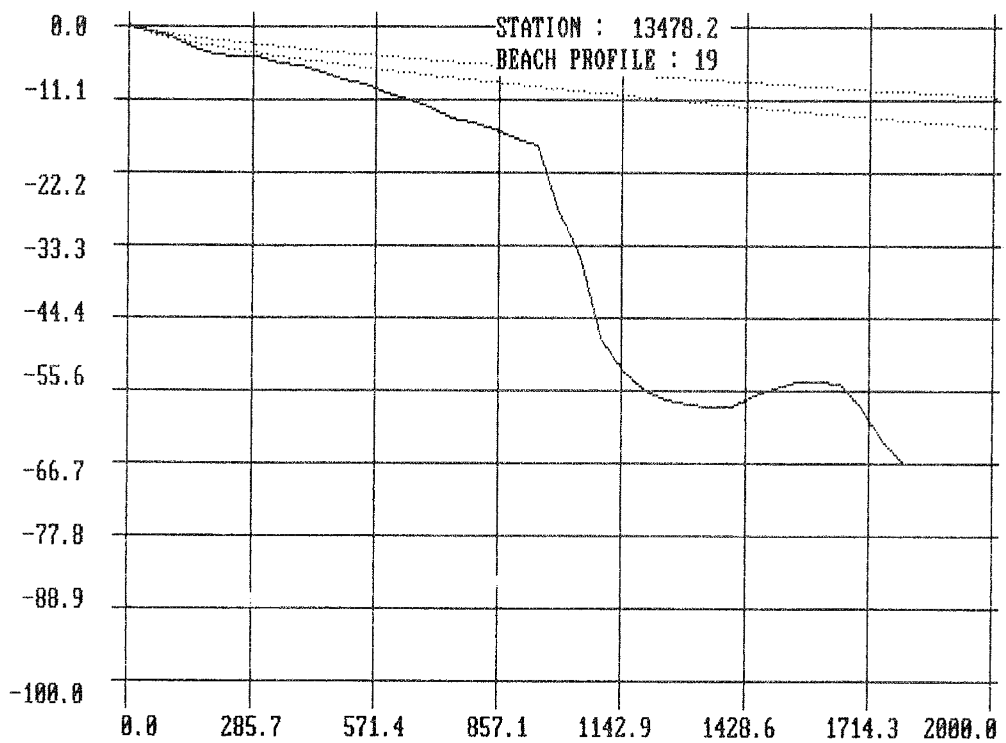
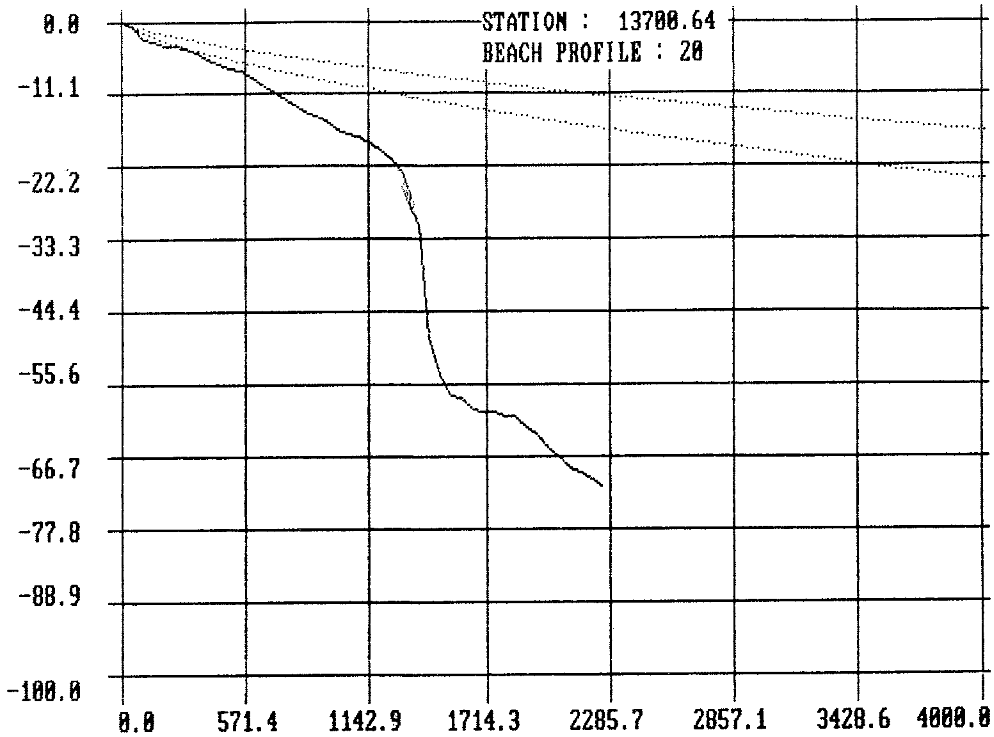
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0


STATION : 13478.2
BEACH PROFILE : 19
0.0
-11.1
-22.2
-33.3
-44.4
-55.6
-66.7
-77.8
-88.9
-100.0
0.0
285.7
571.4
857.1
1142.9
1428.6
1714.3
2000.0



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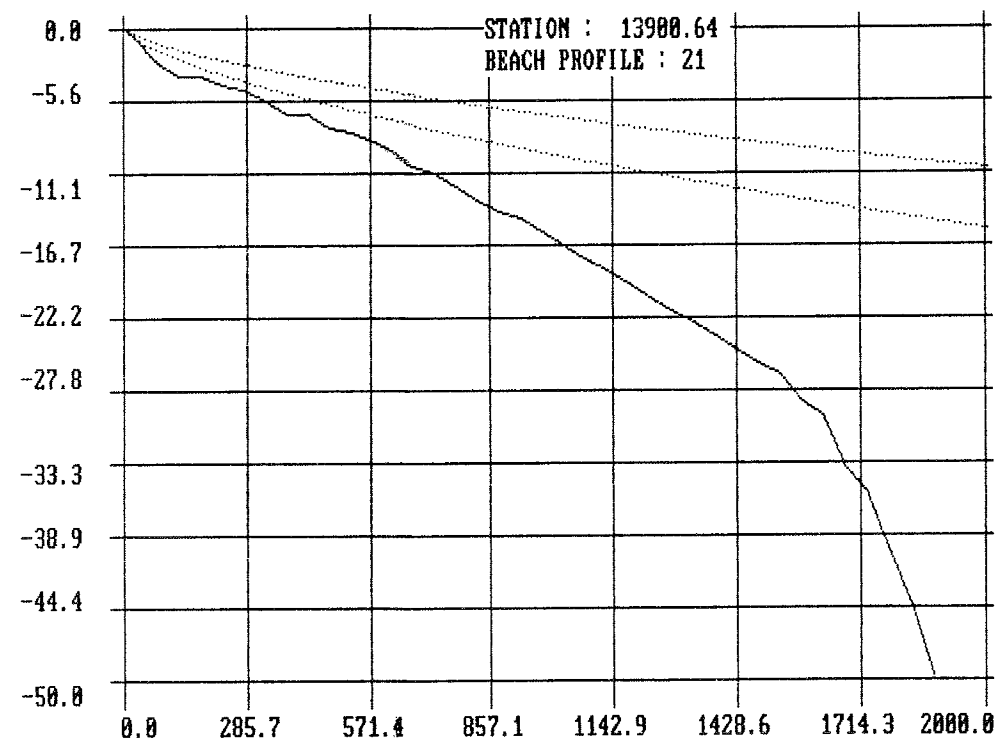

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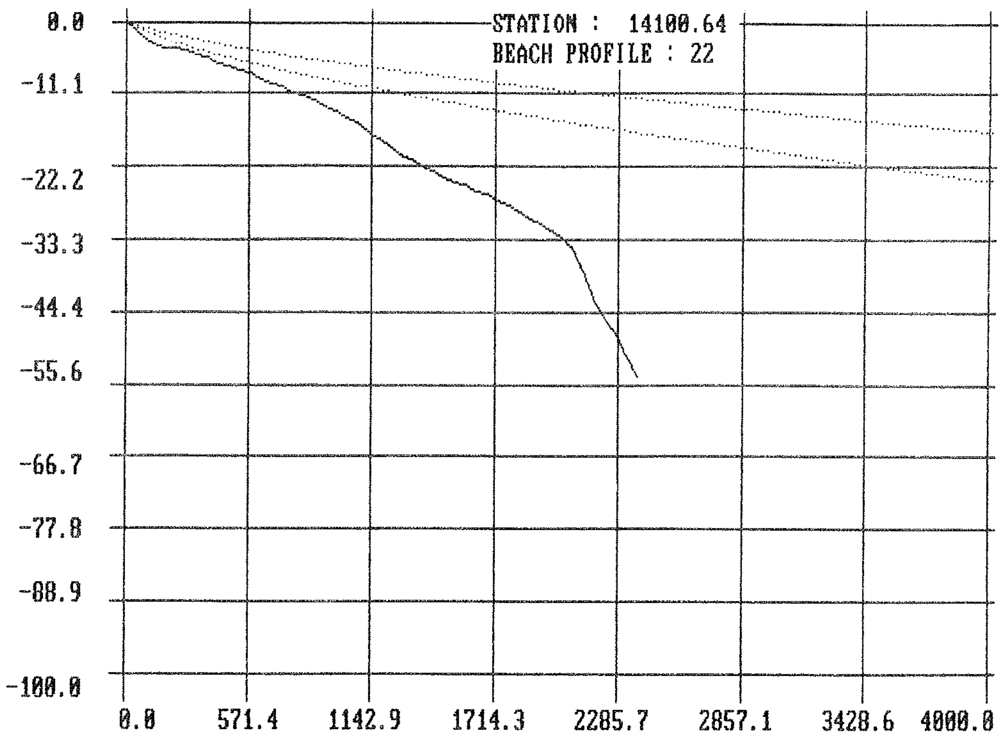
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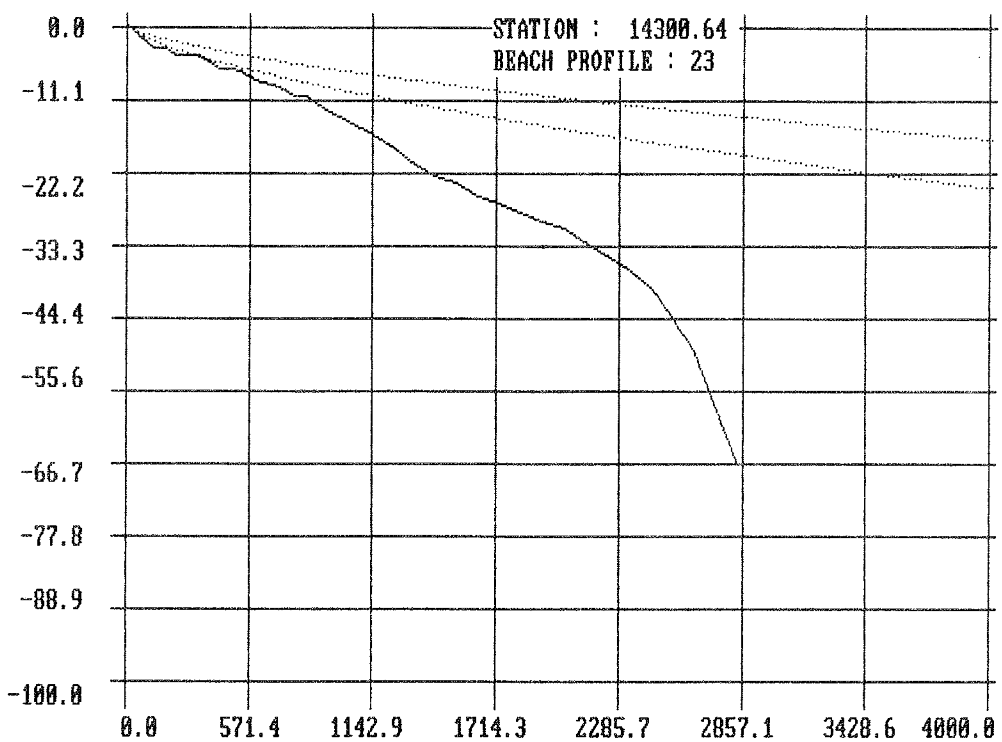
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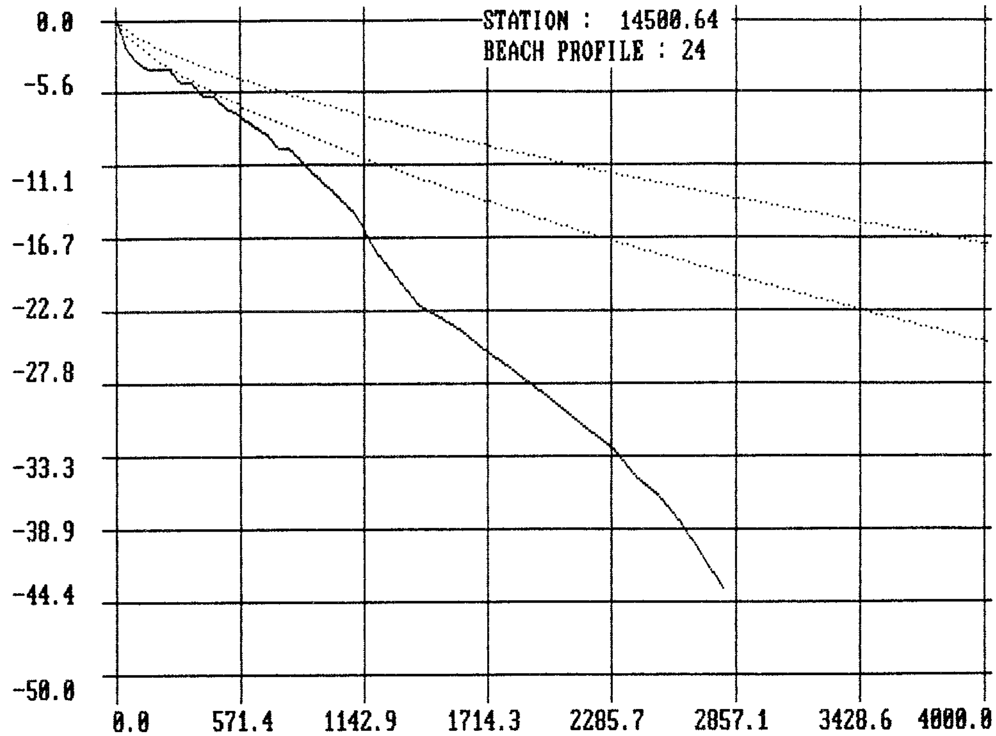
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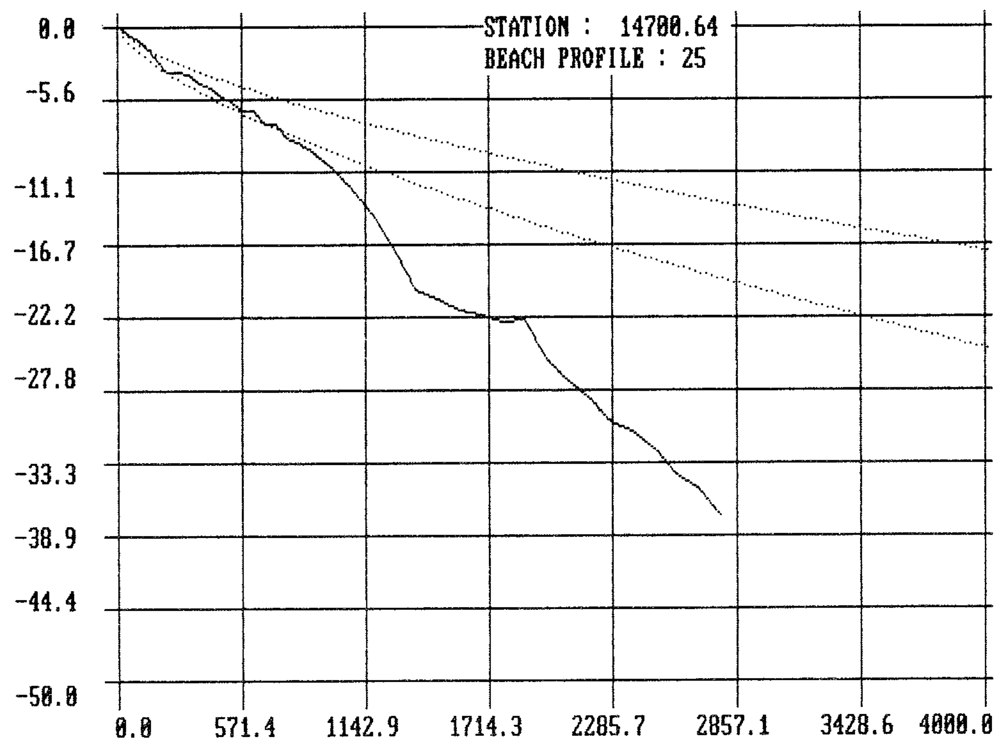
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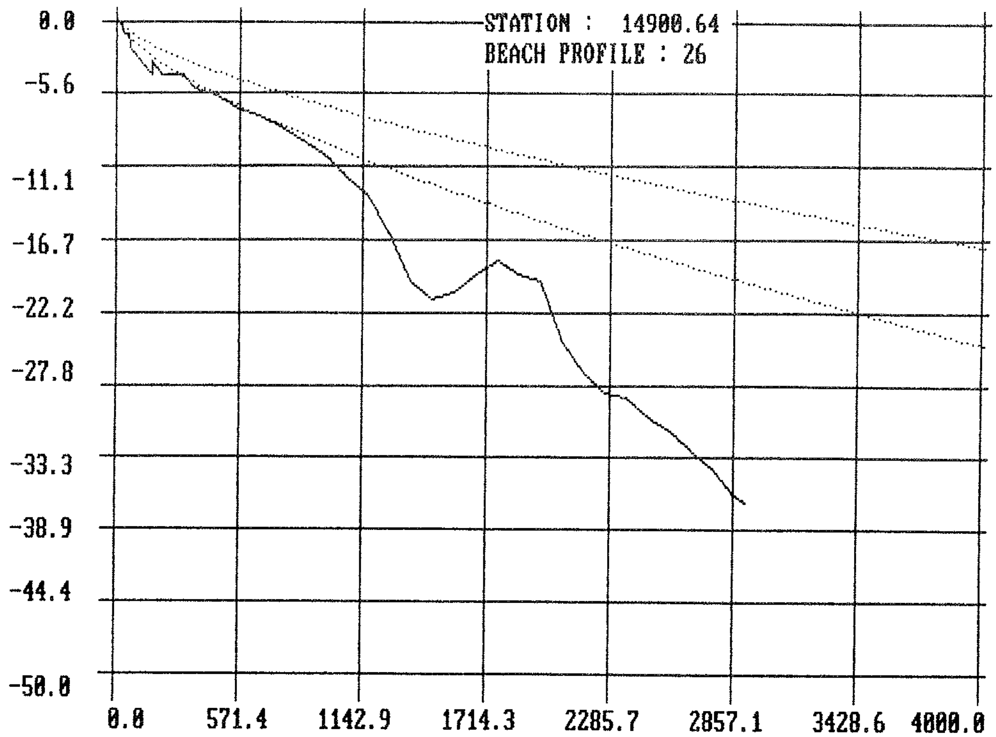
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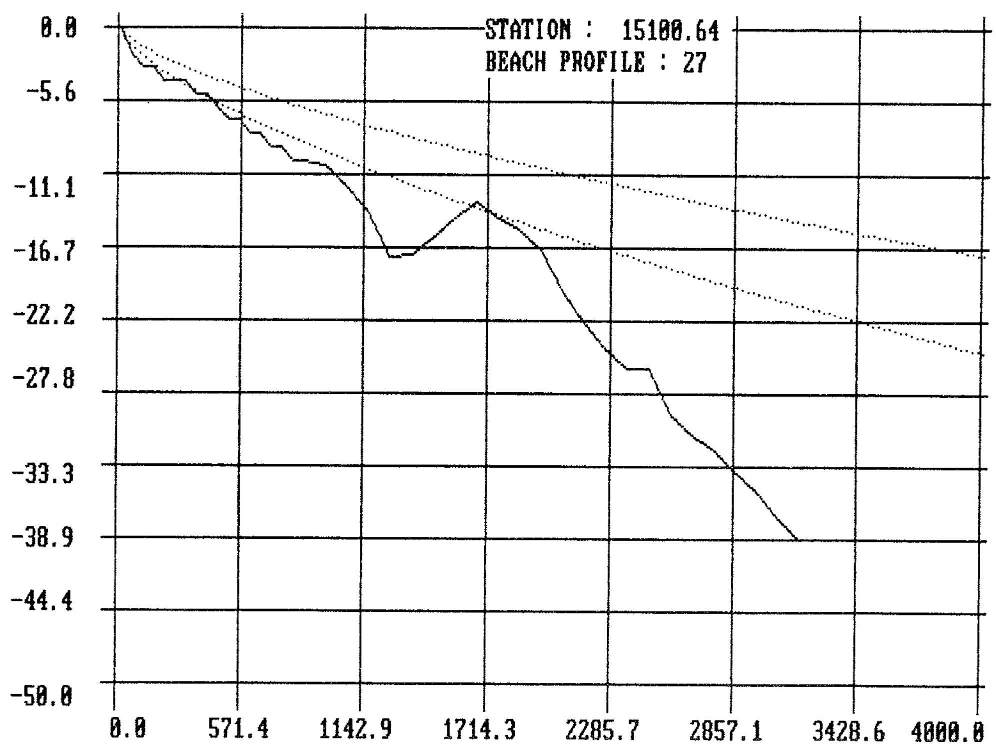
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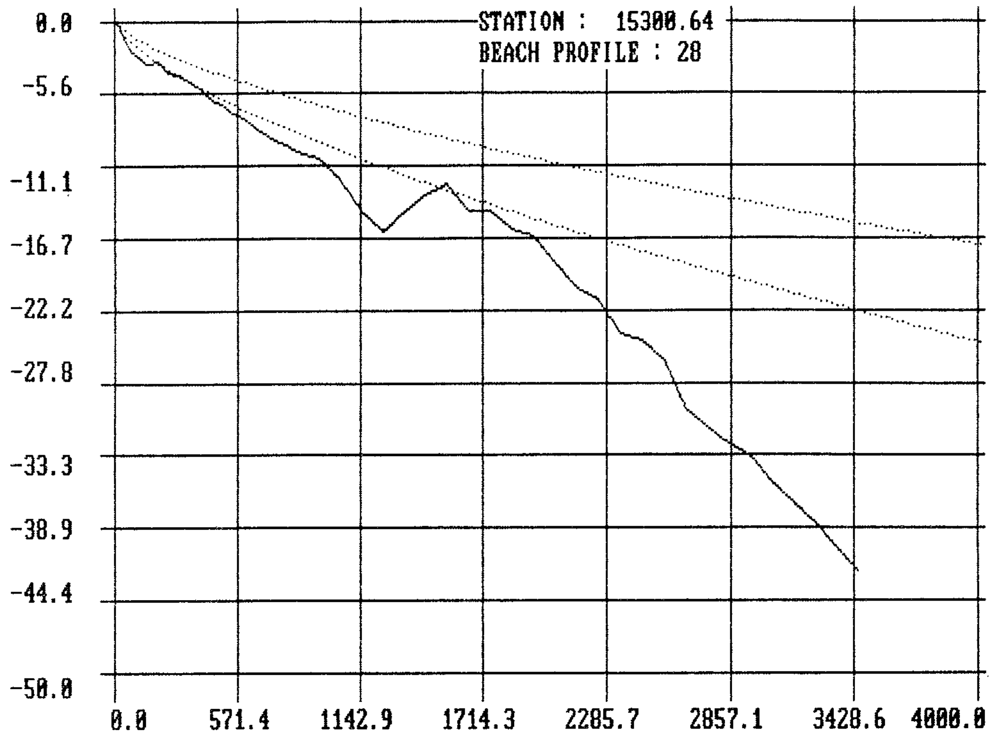
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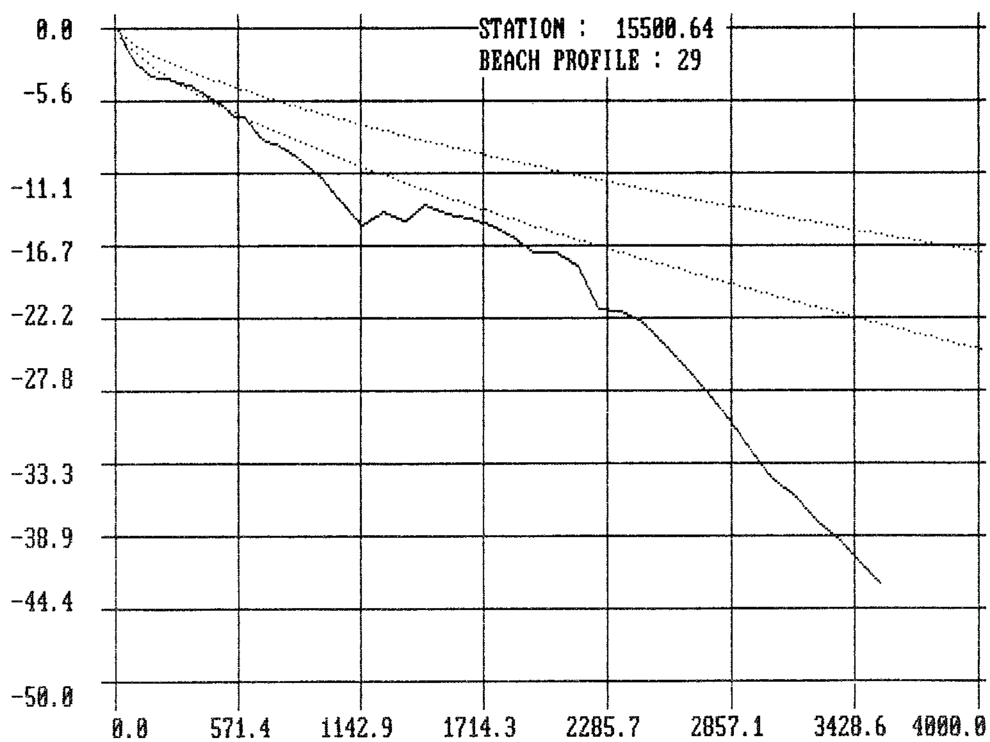
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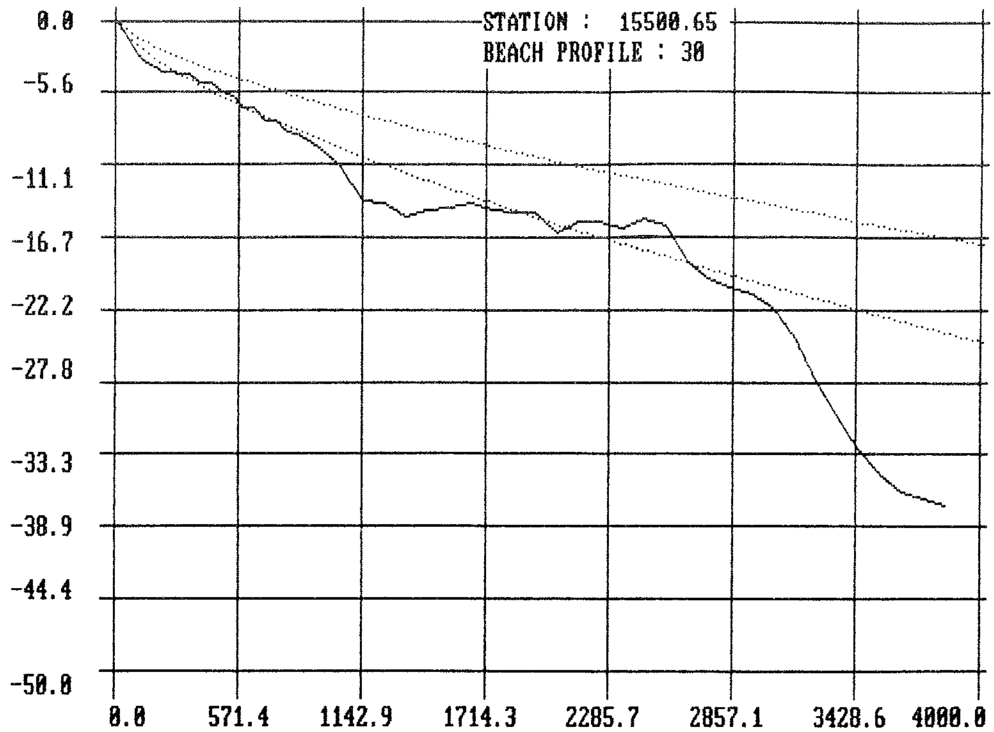
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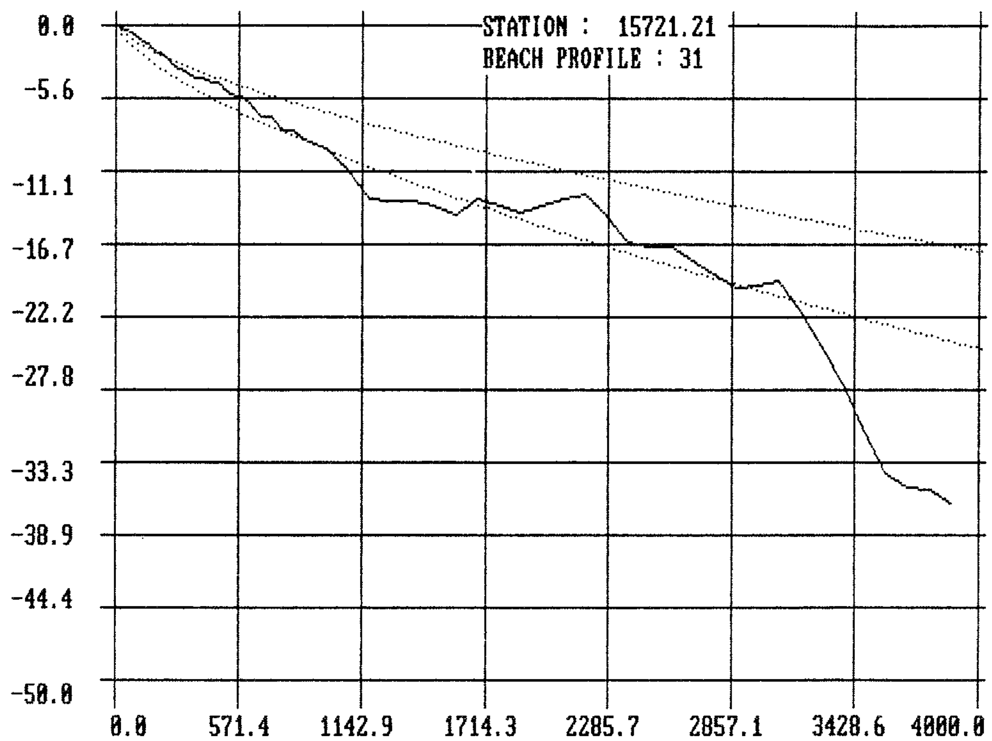
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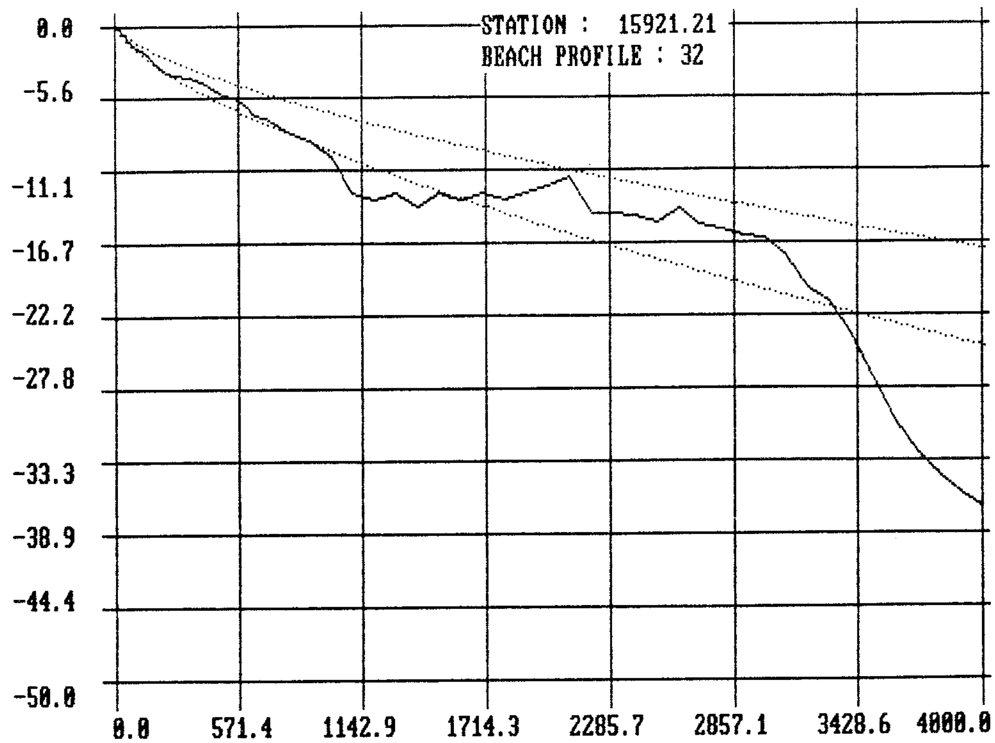
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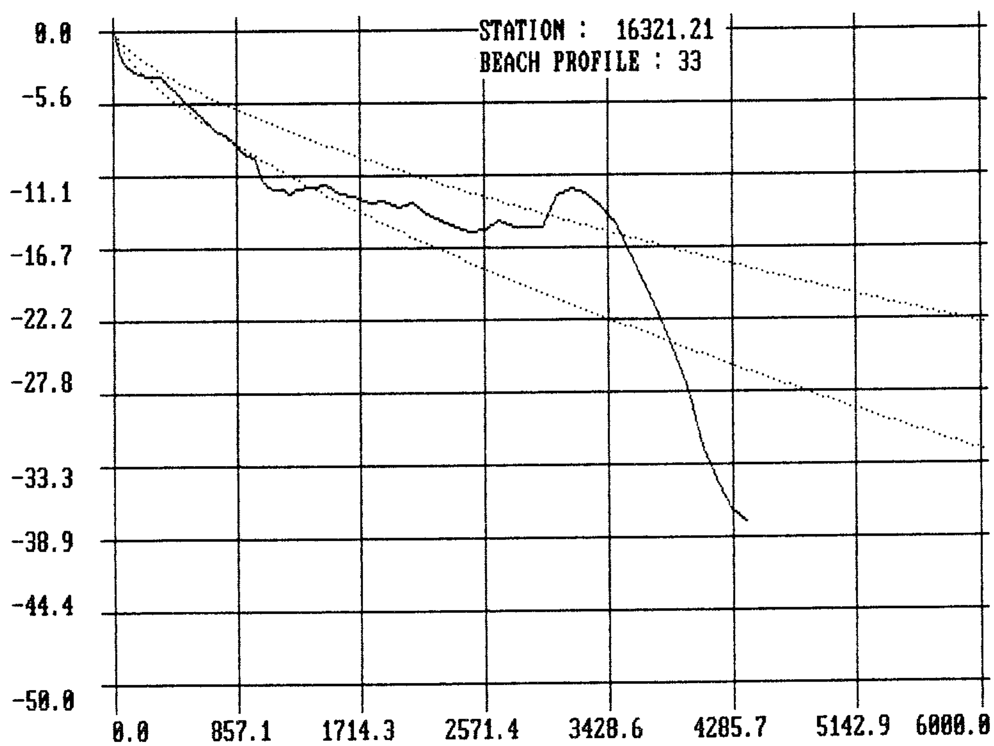
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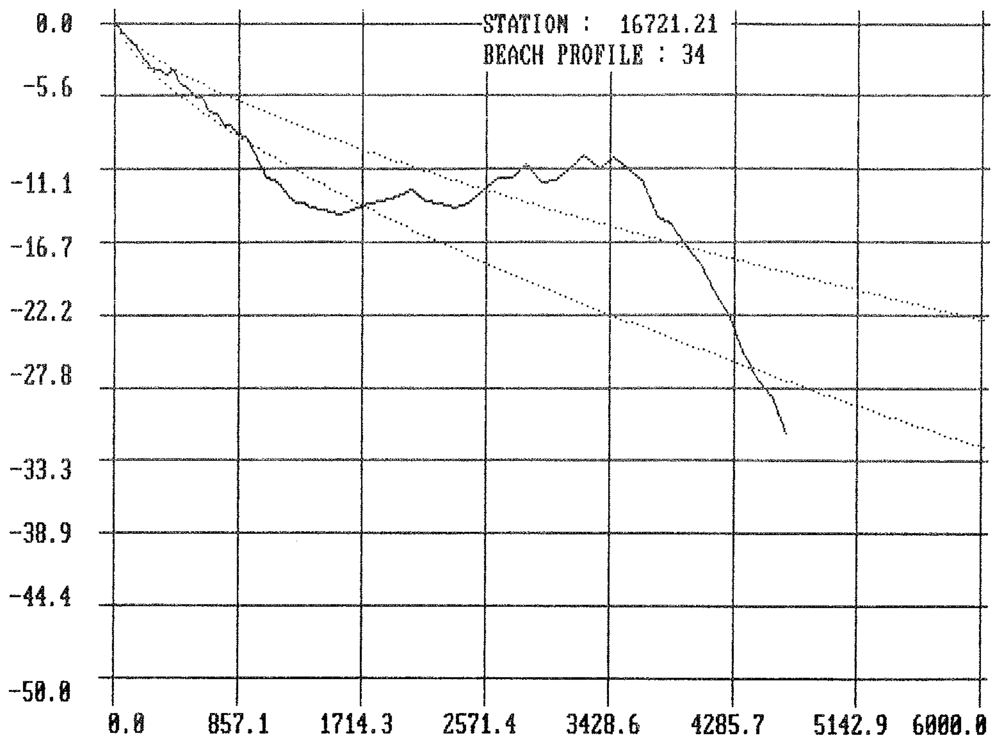
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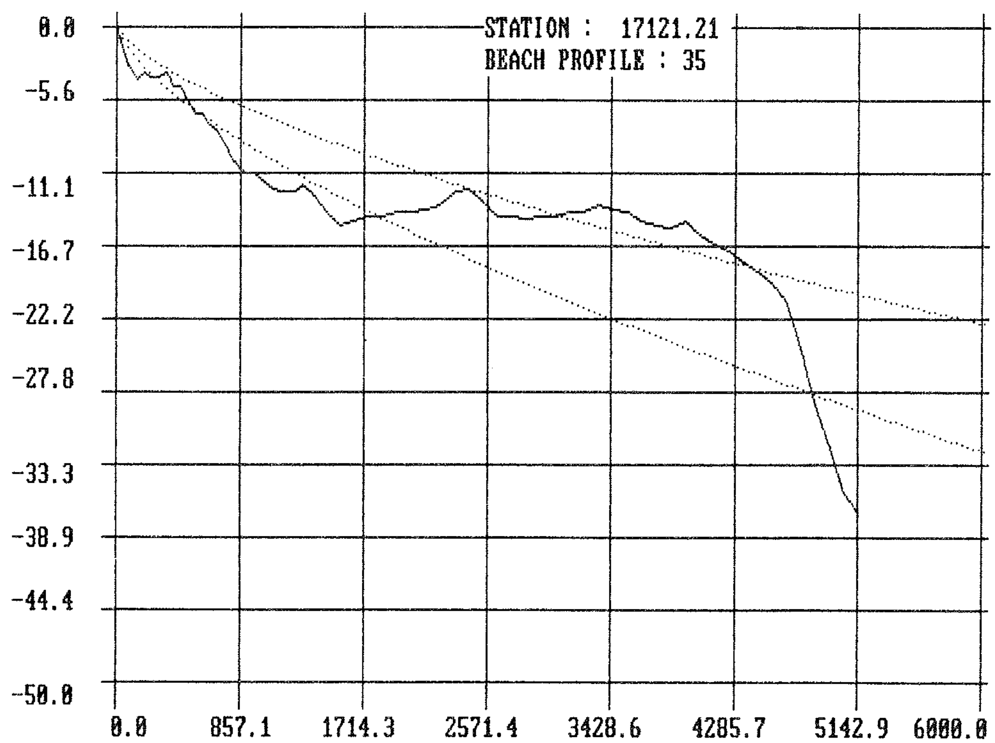
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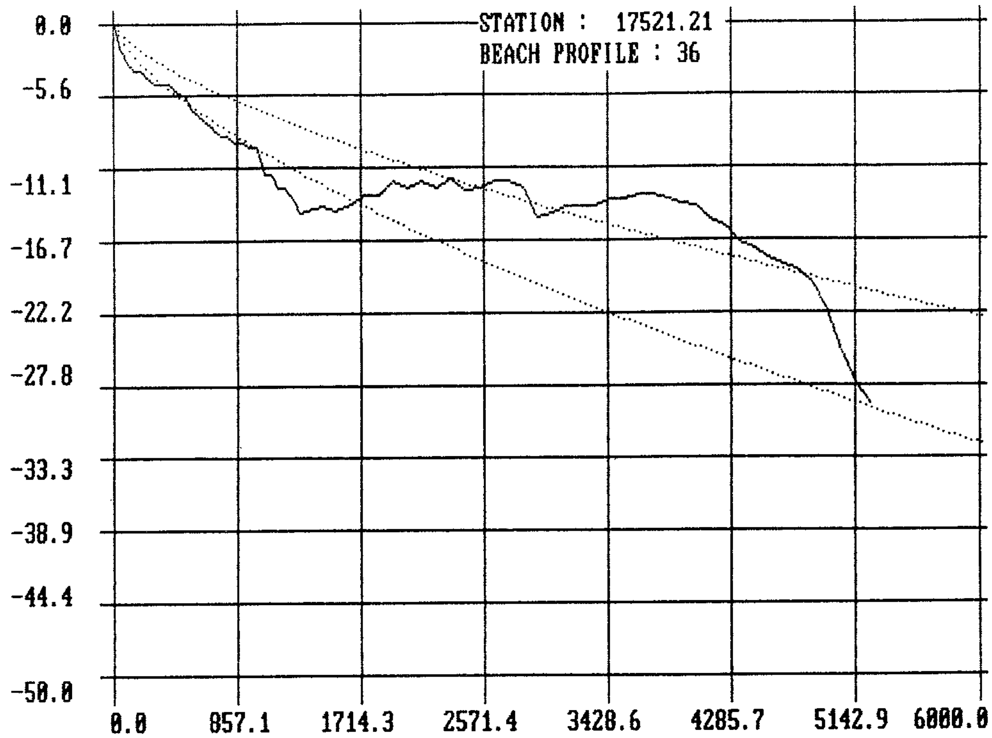
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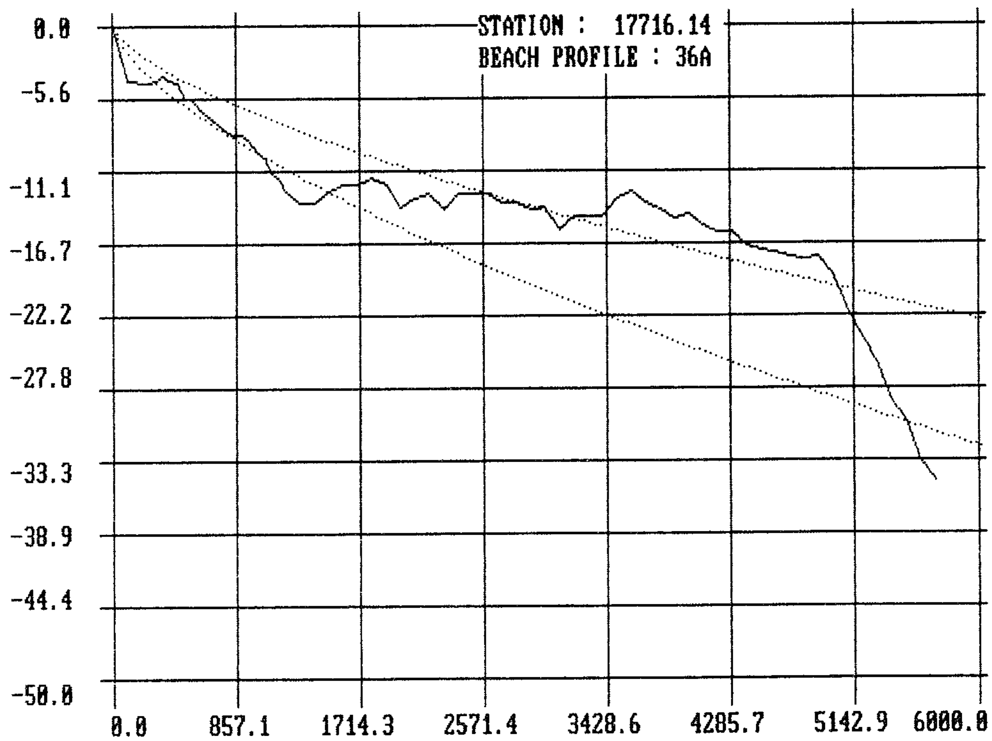
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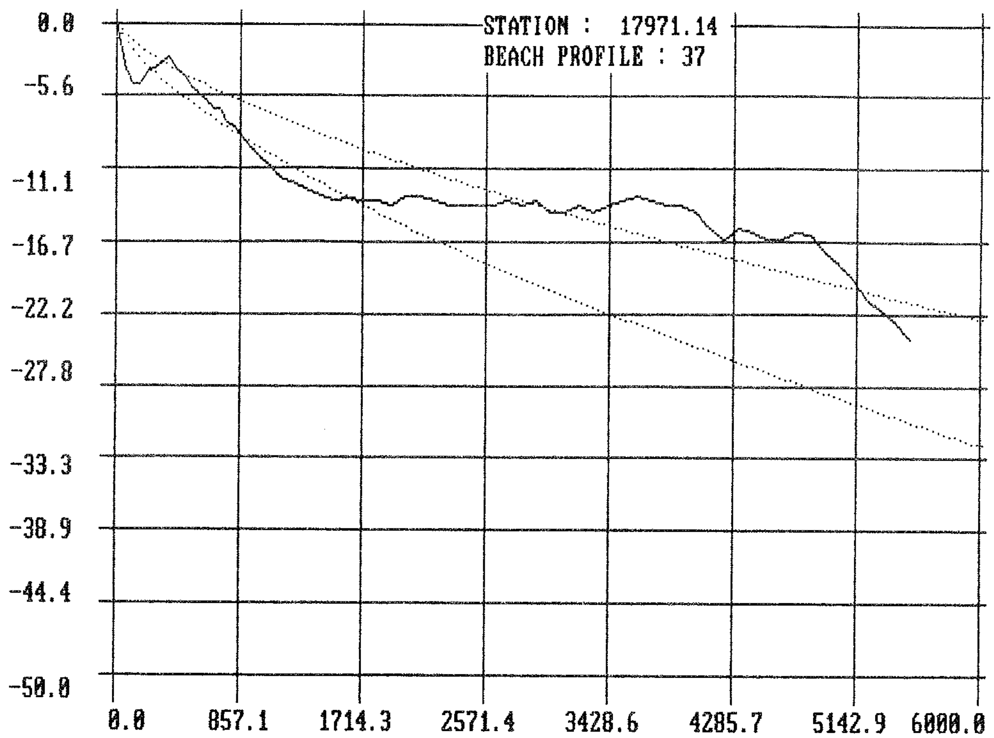
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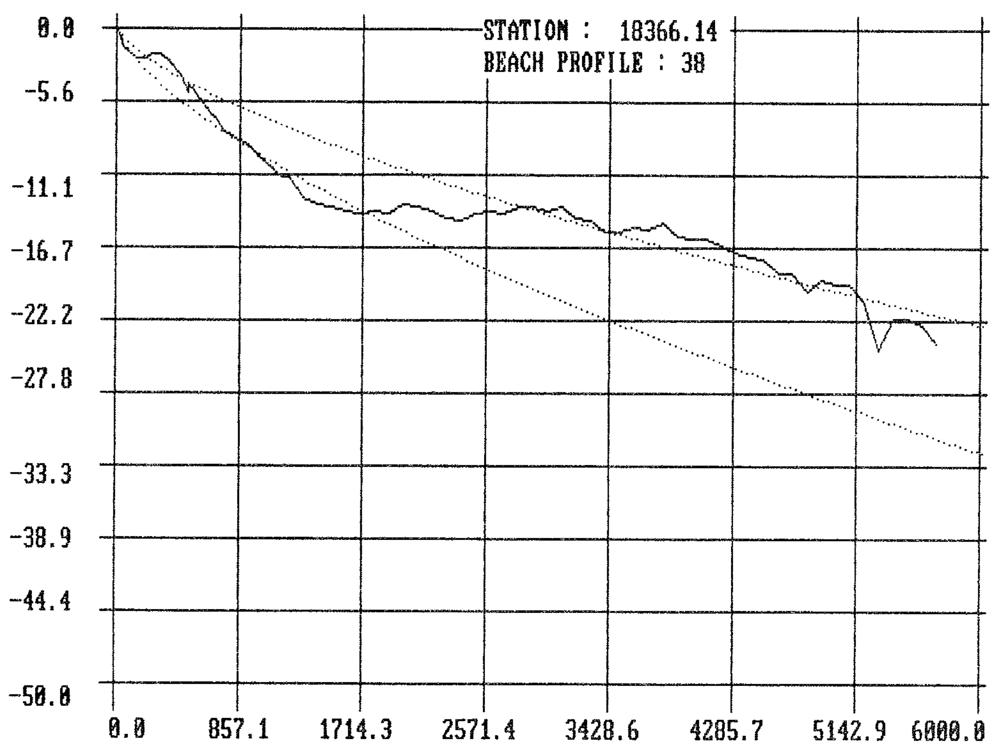
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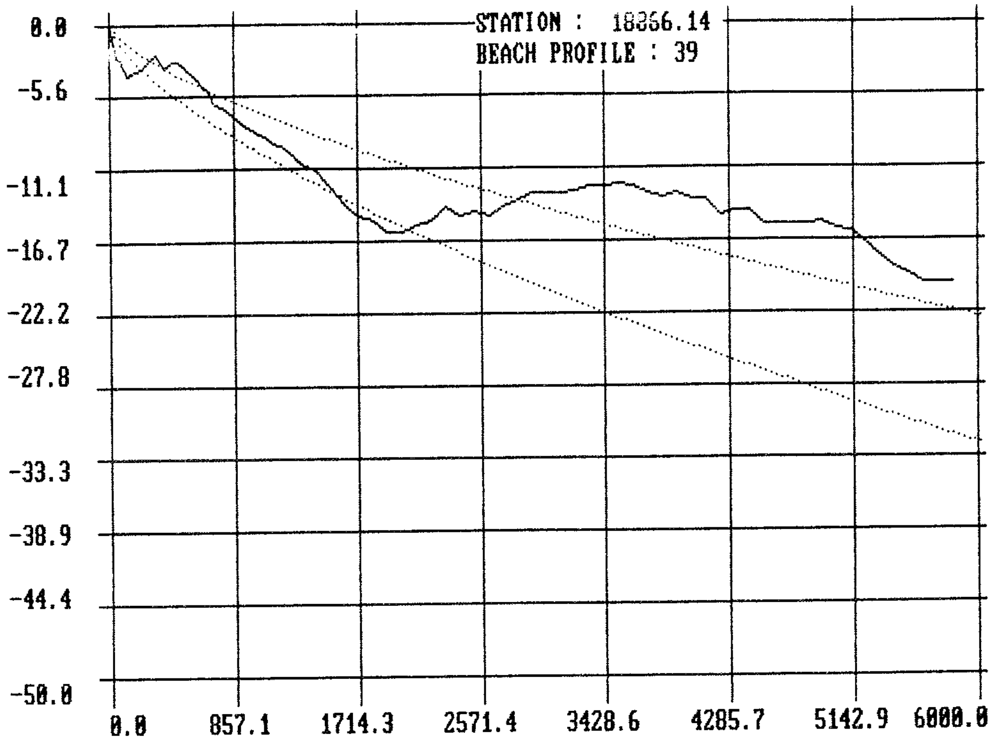
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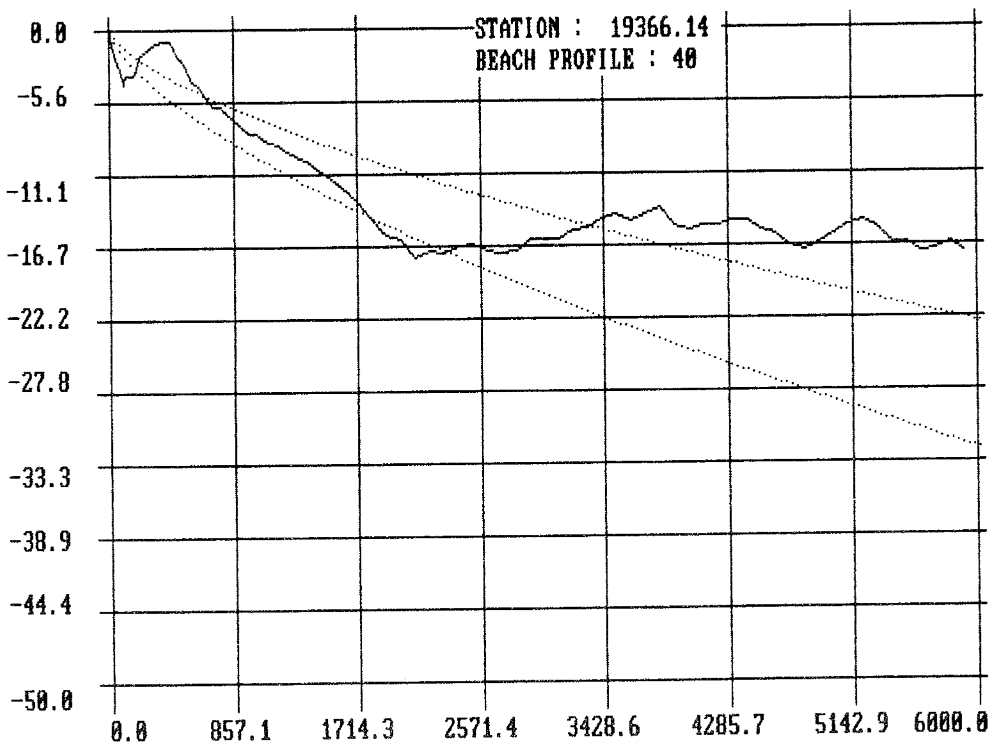
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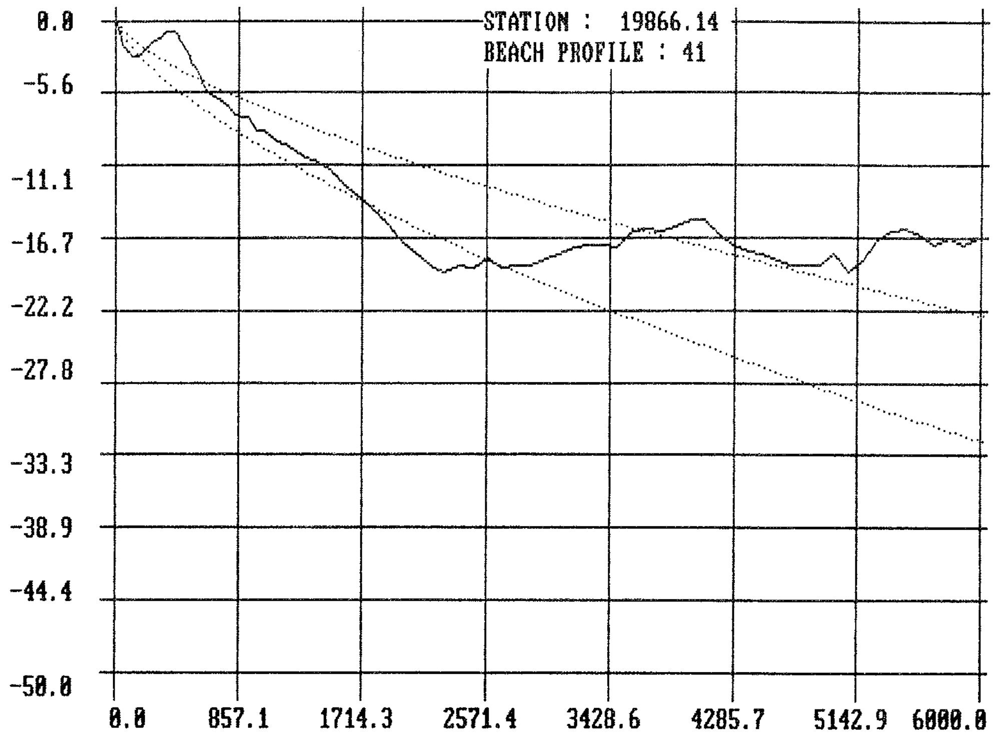
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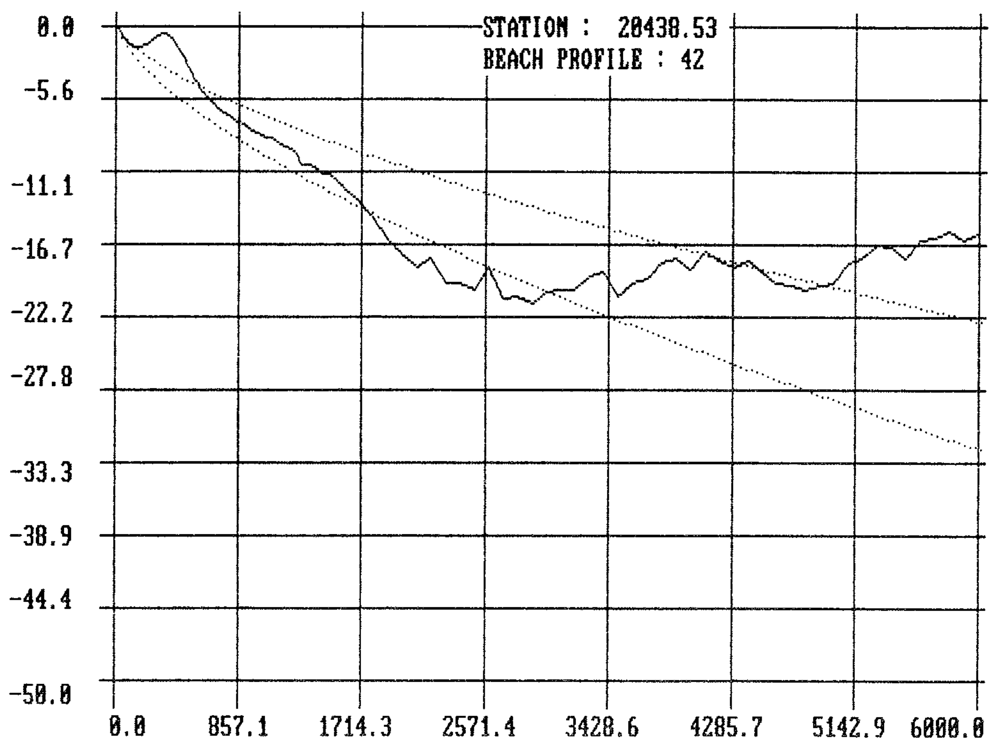
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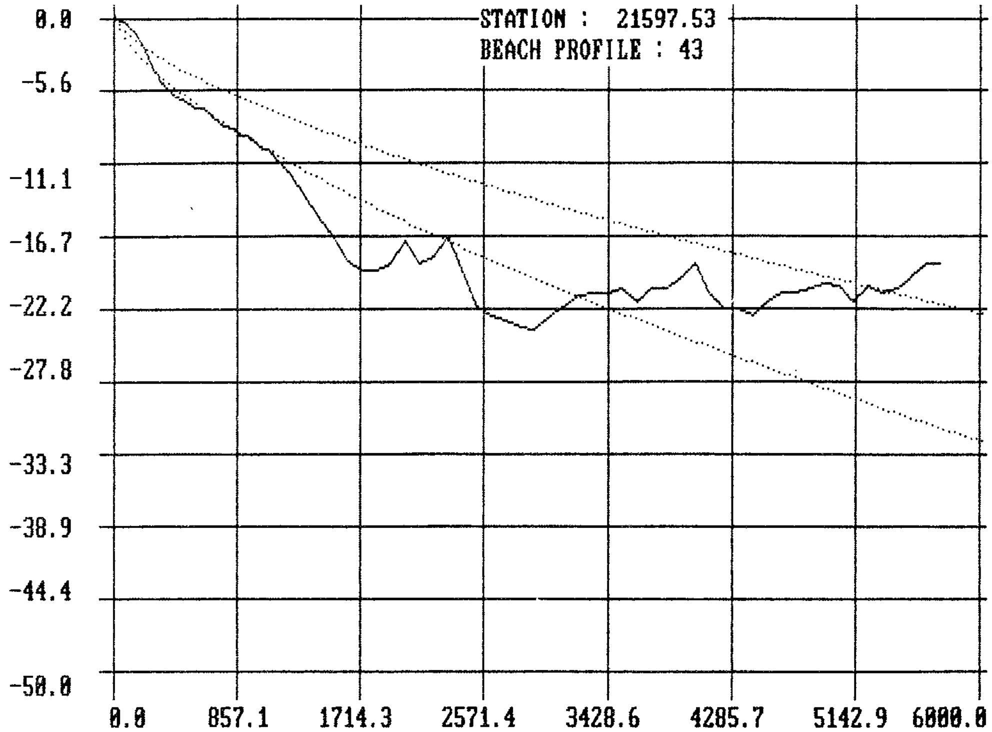
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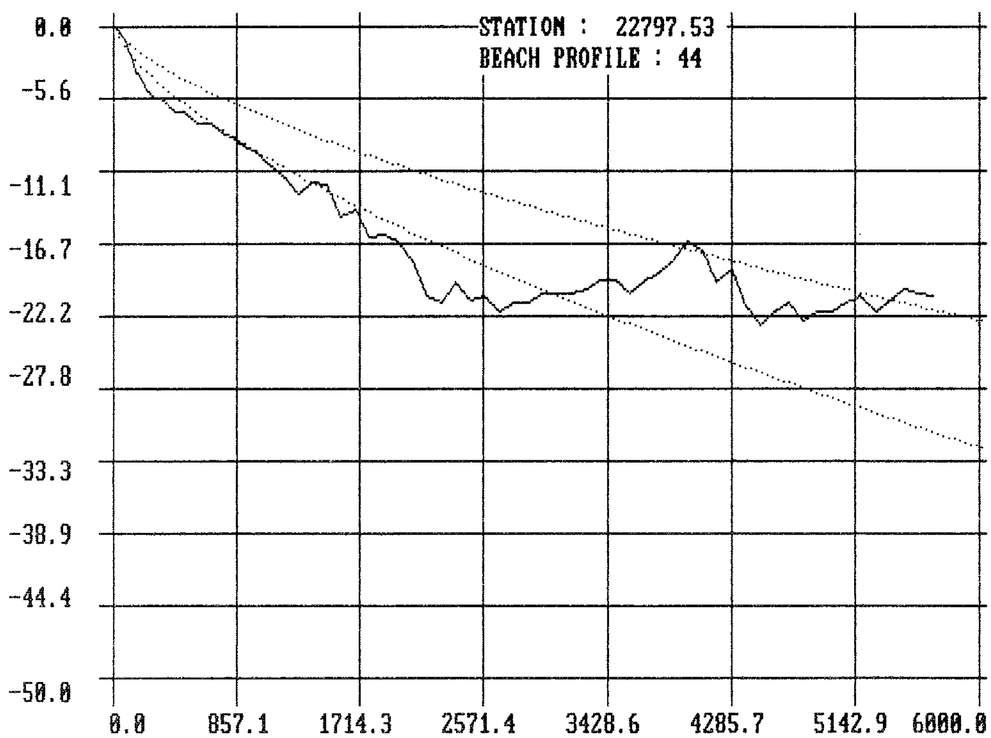
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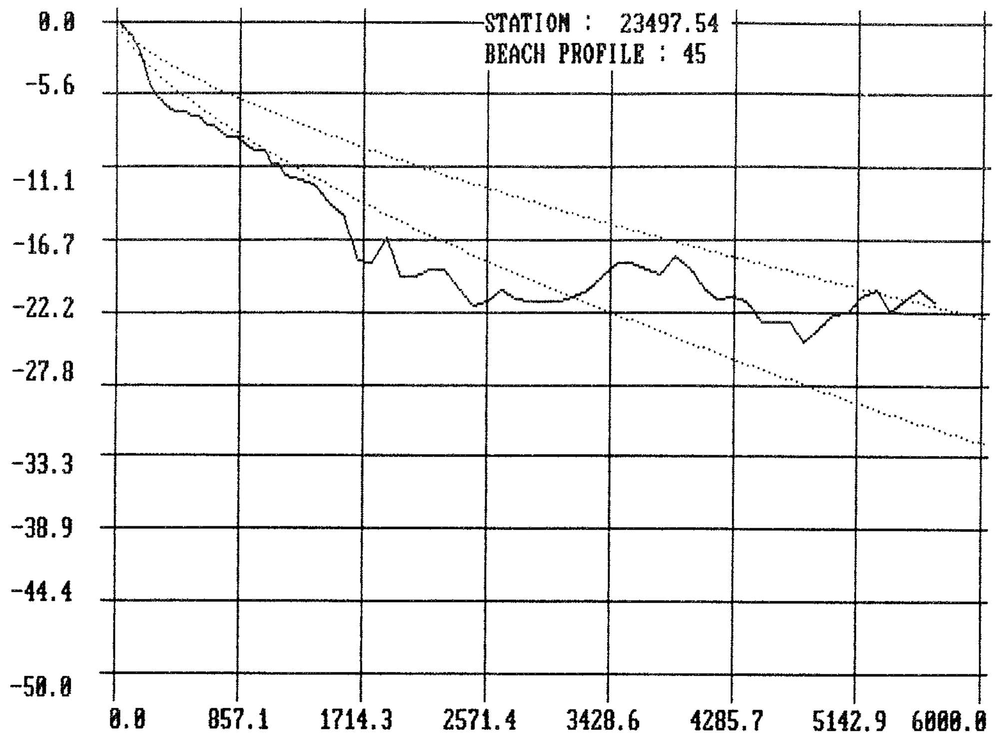
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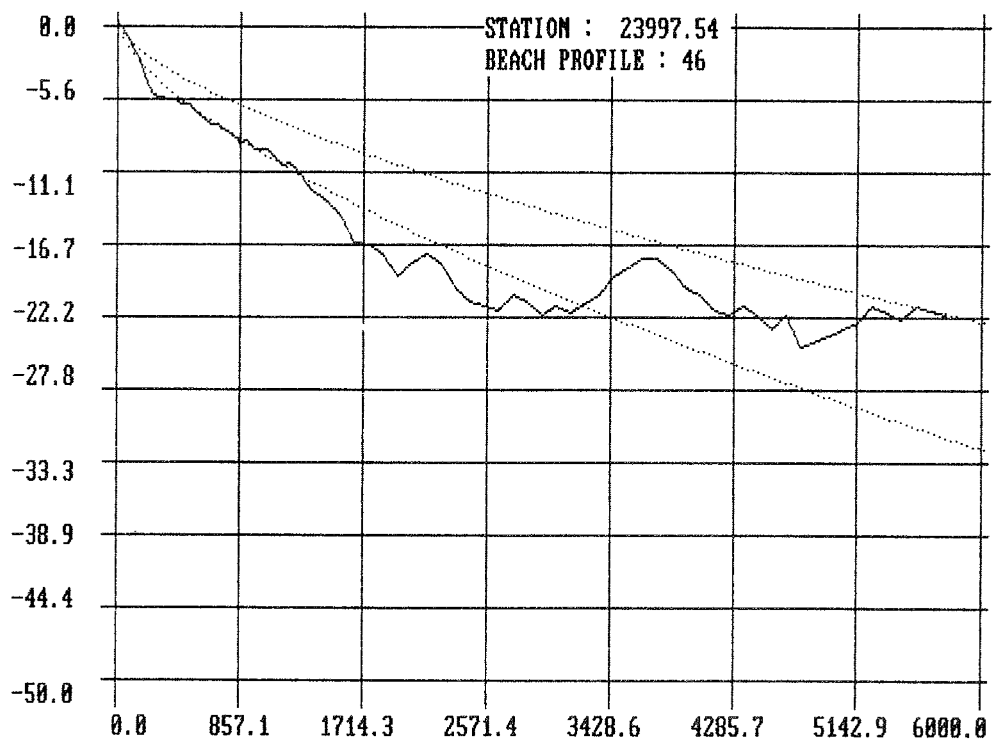
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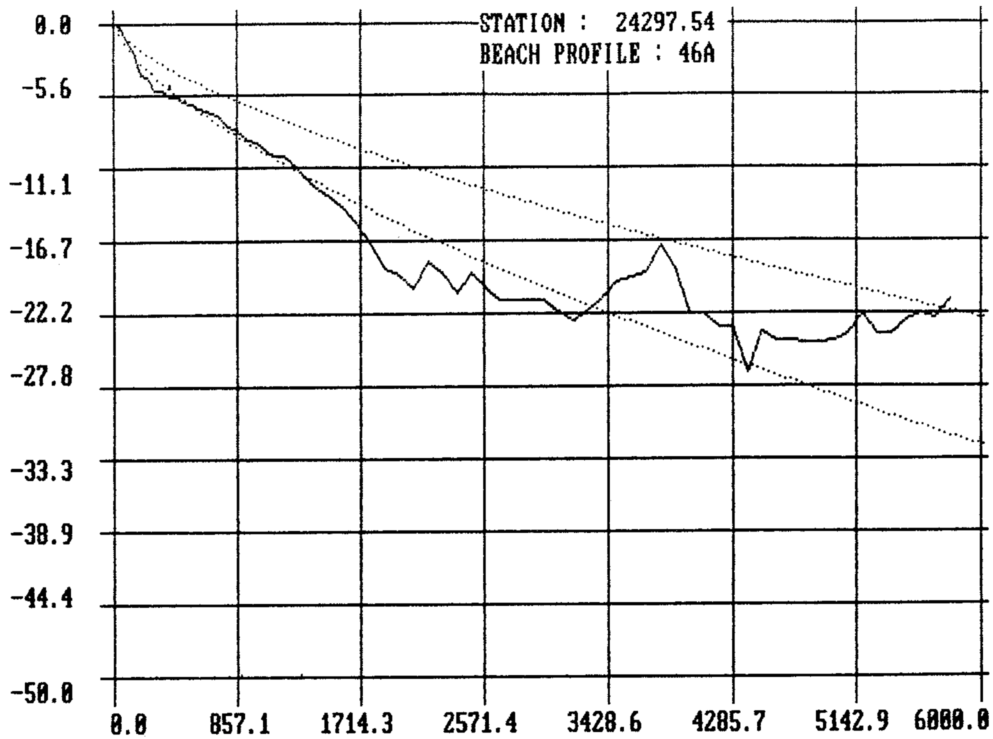
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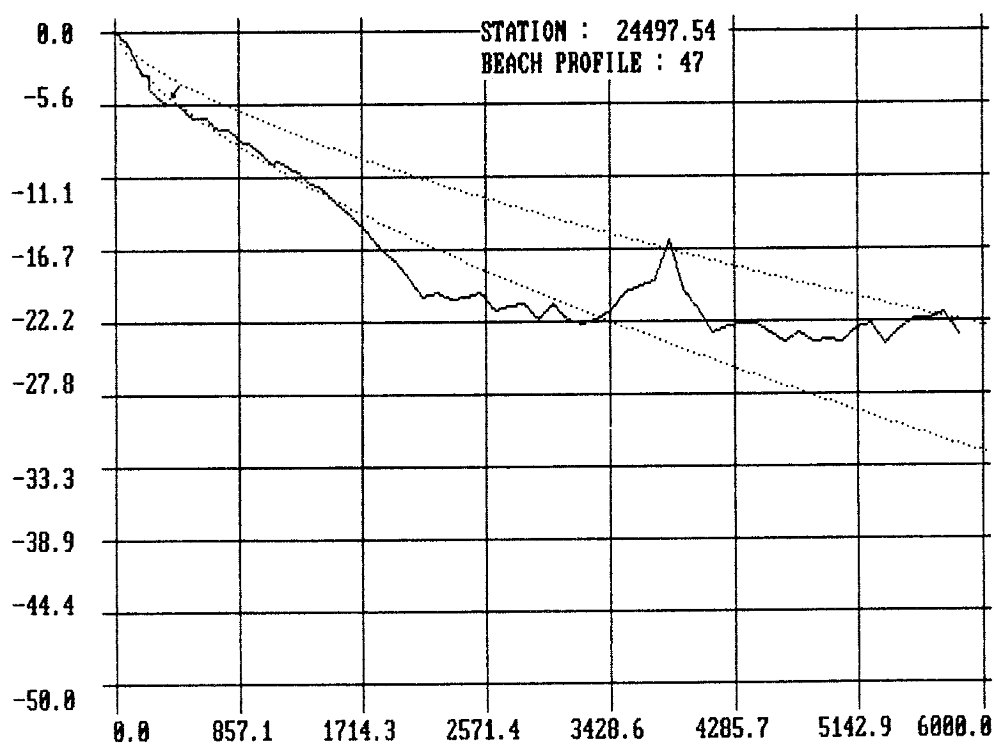
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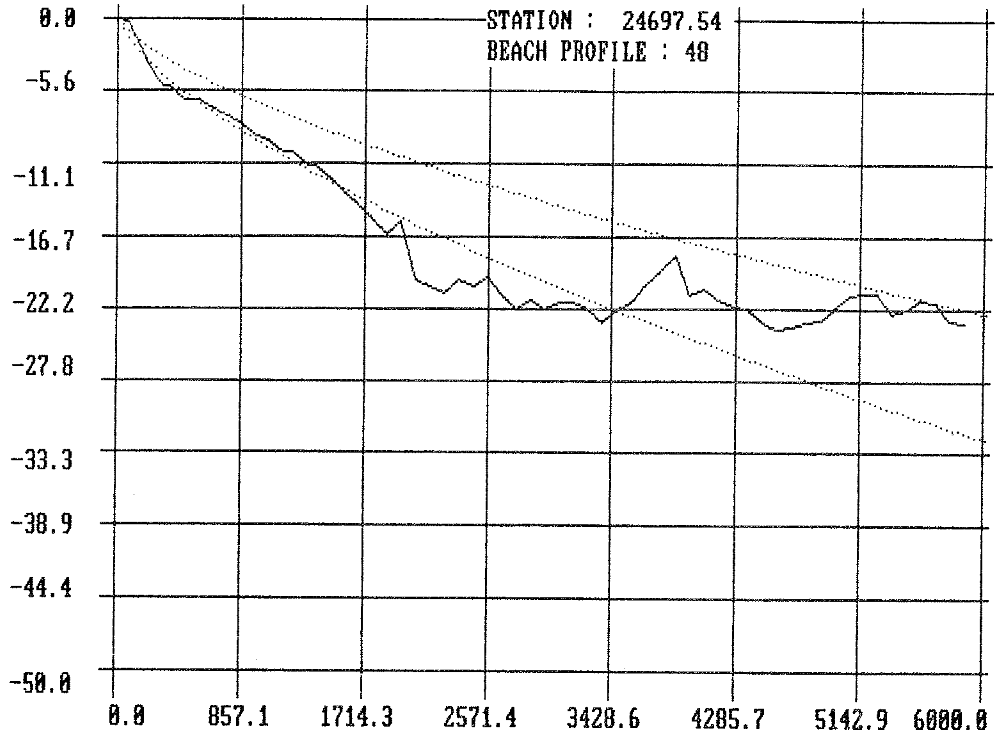
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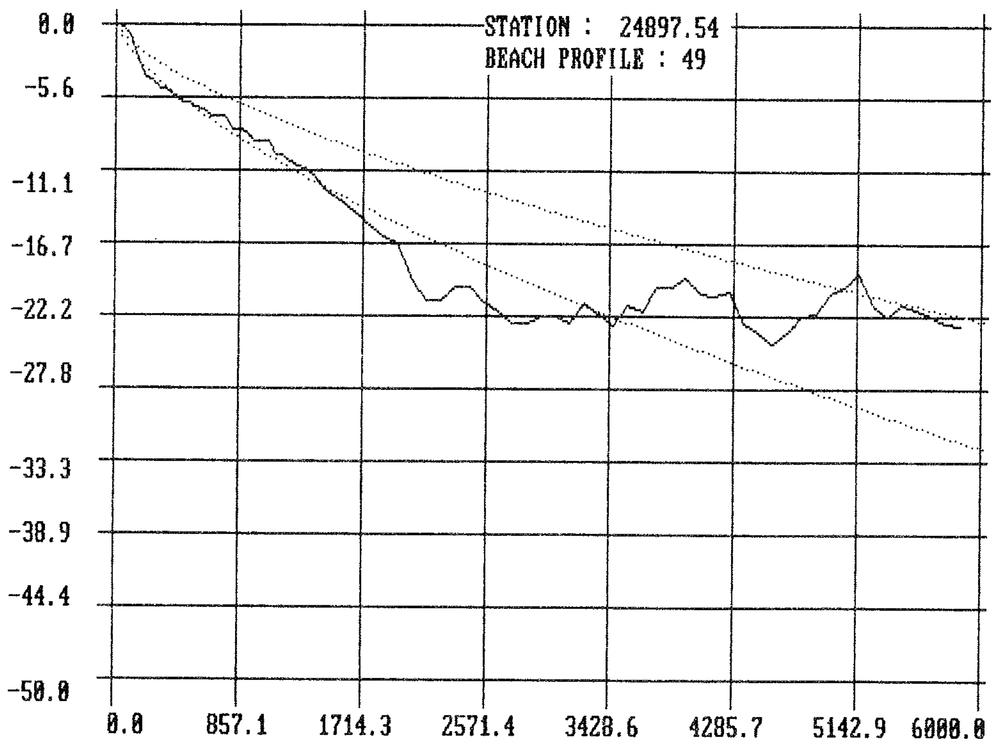
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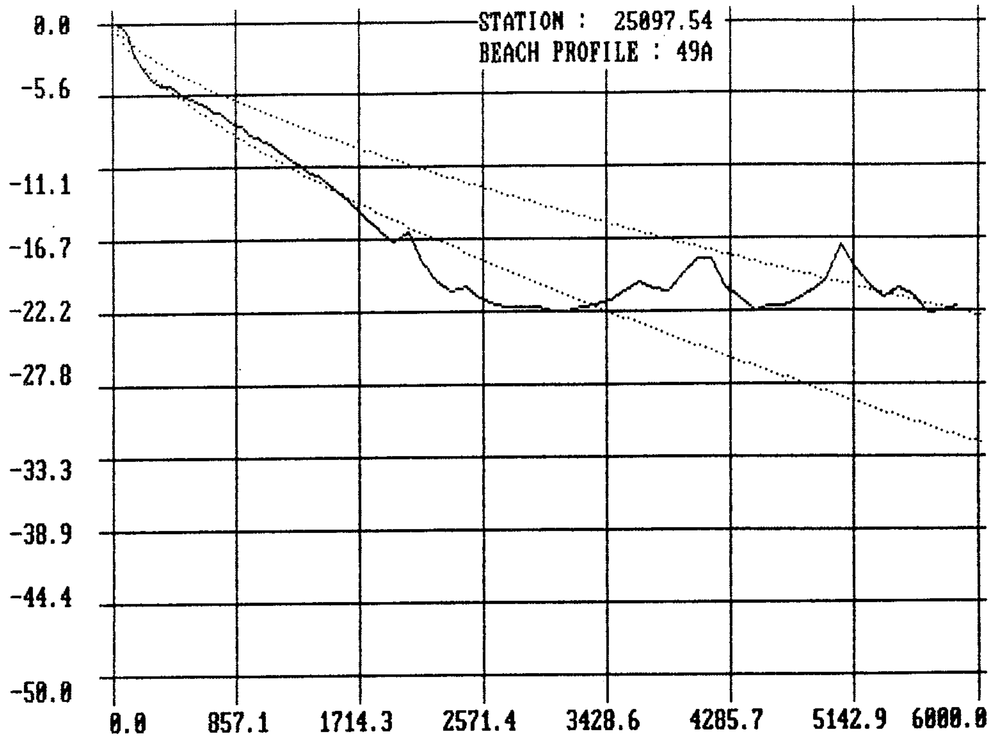
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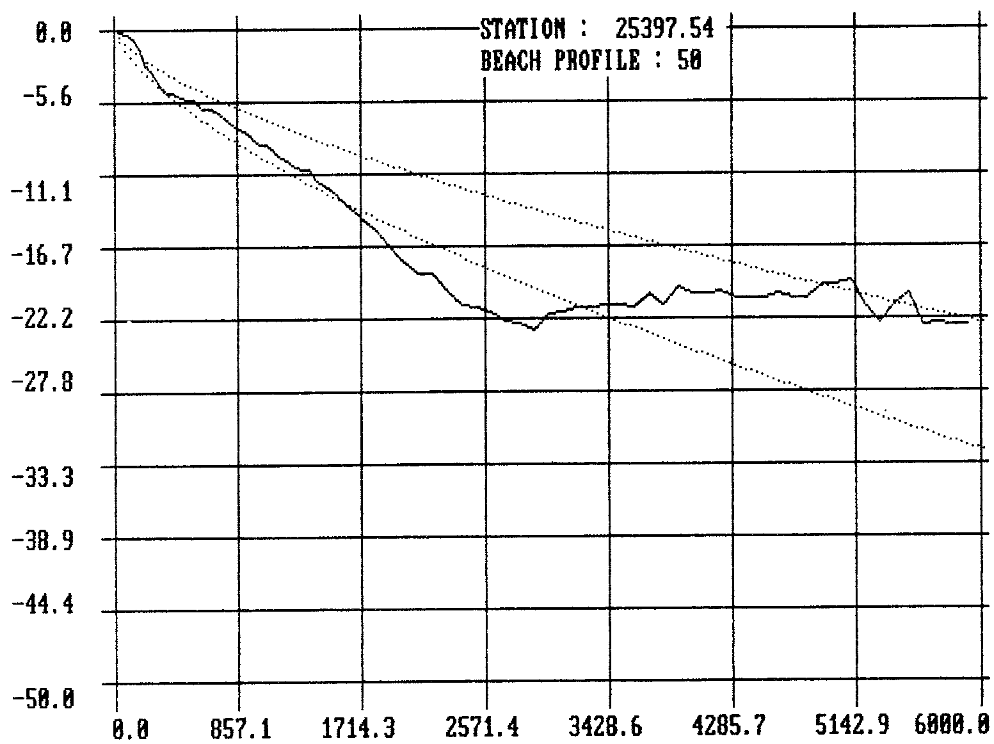
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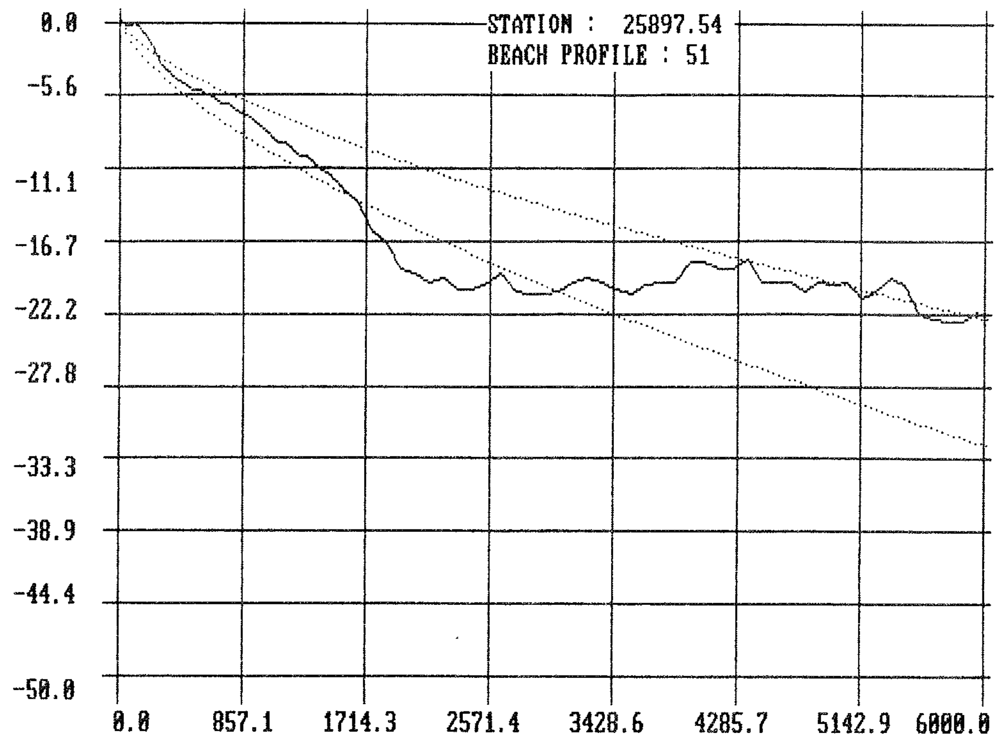
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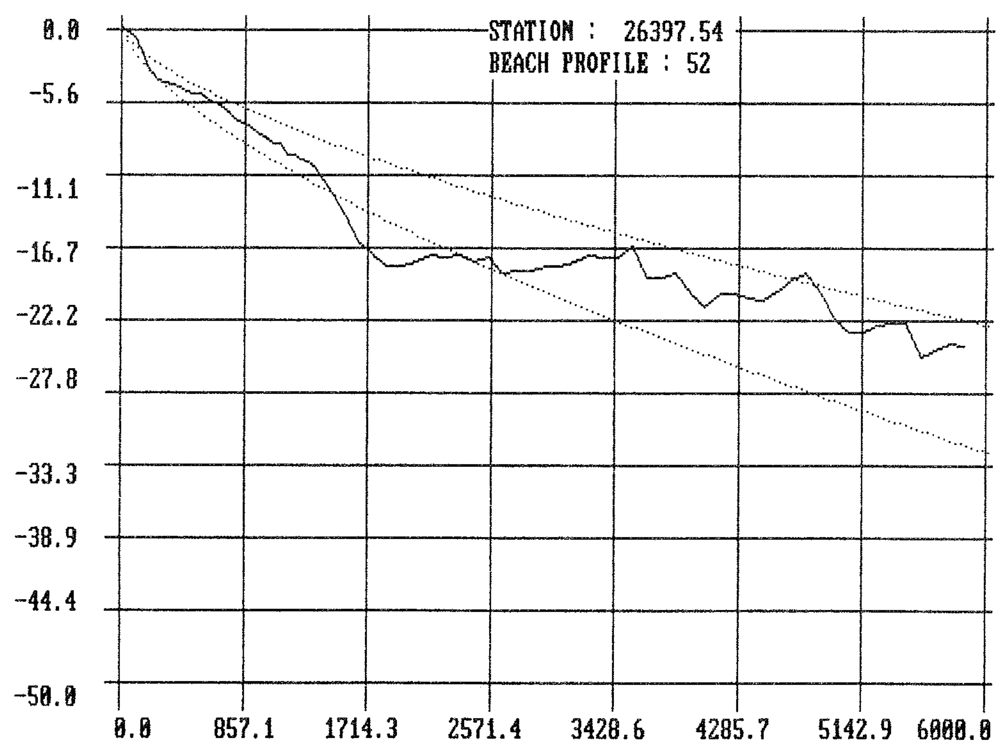
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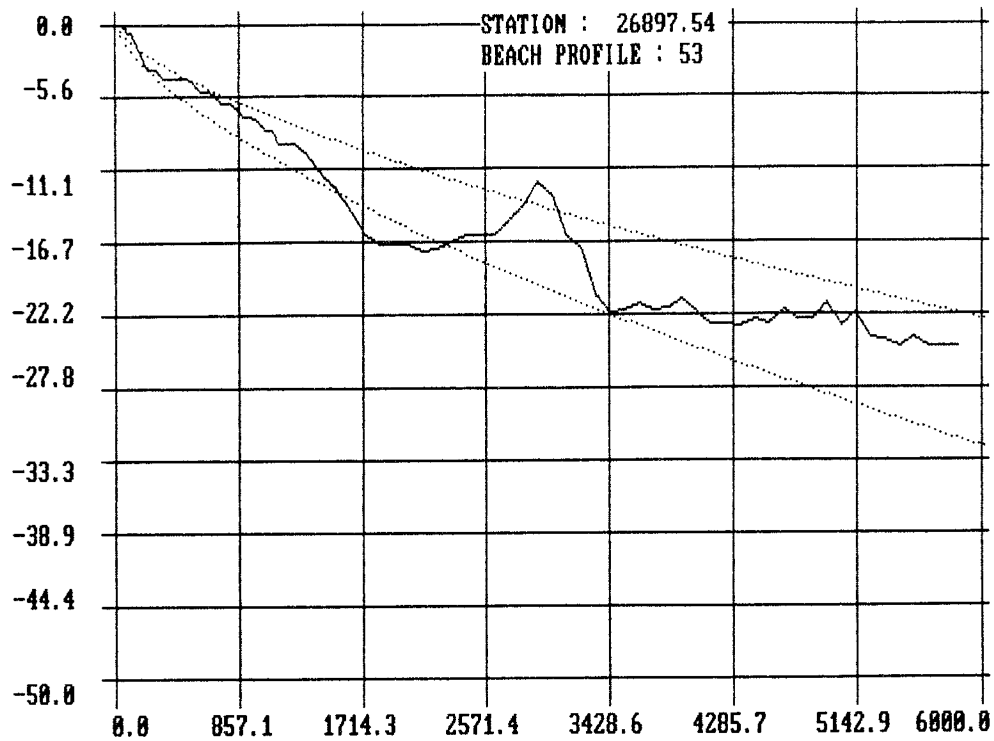
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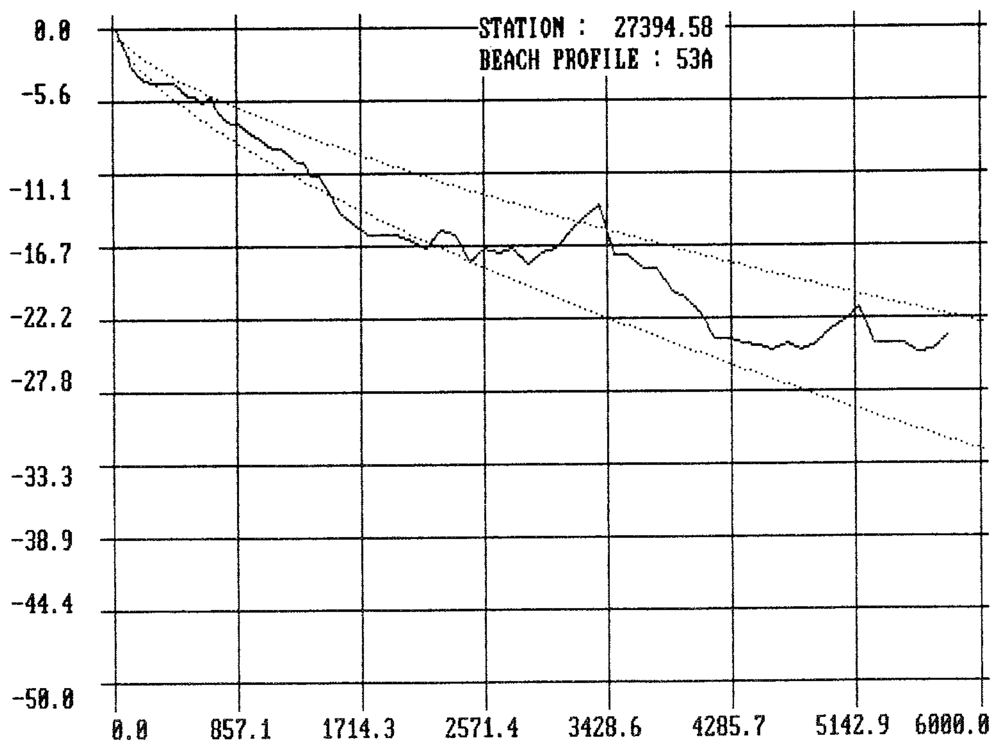
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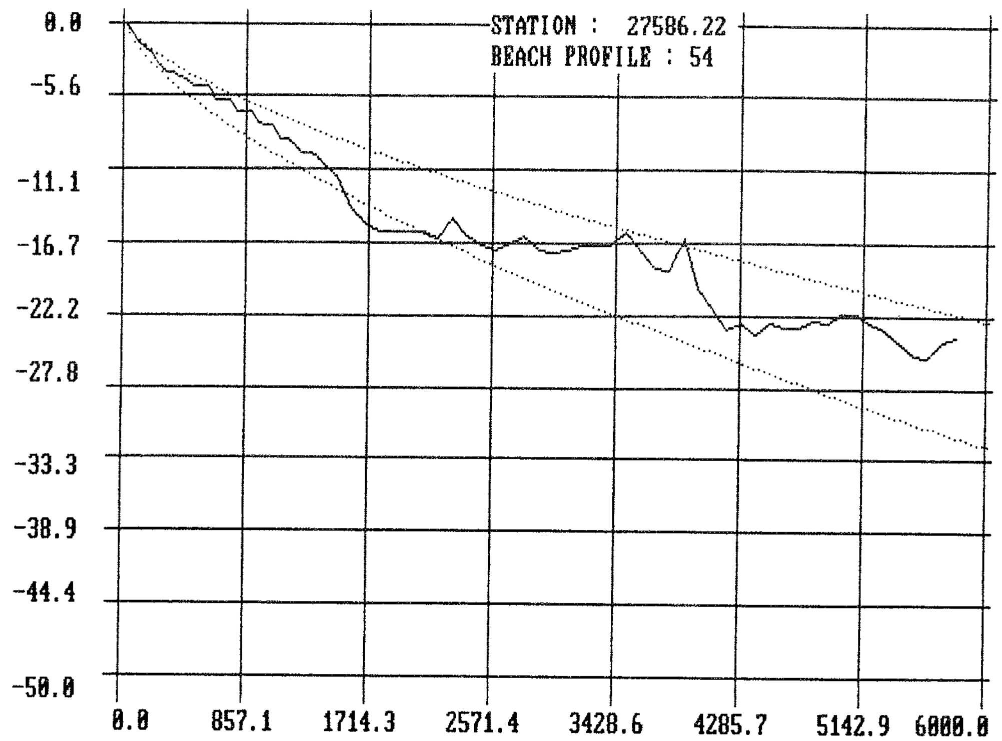
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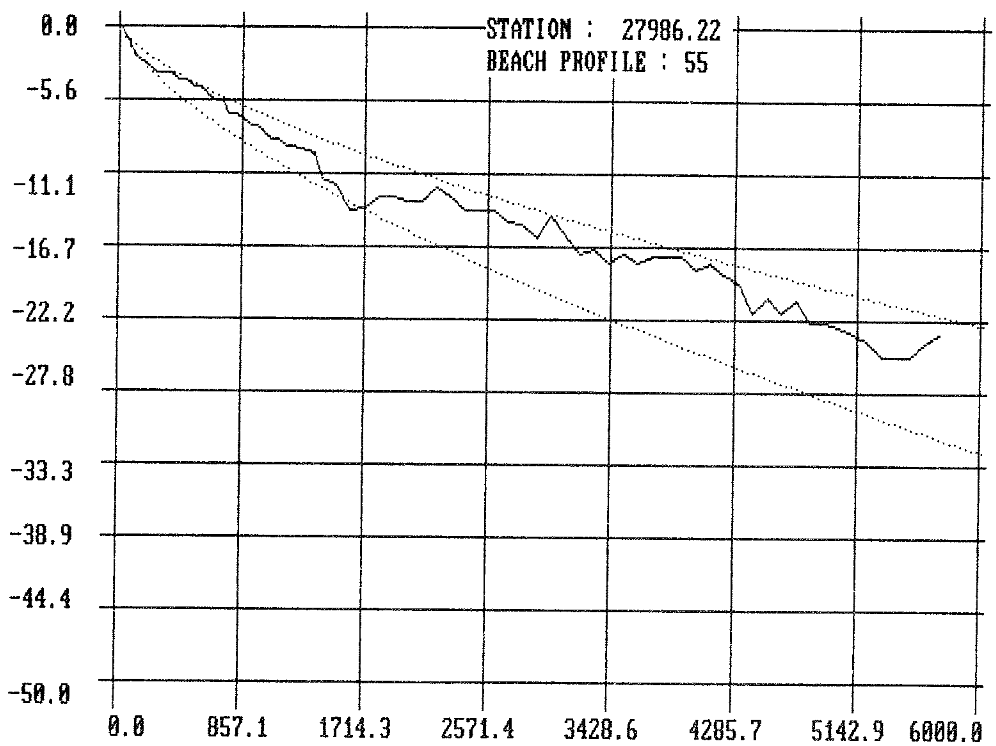
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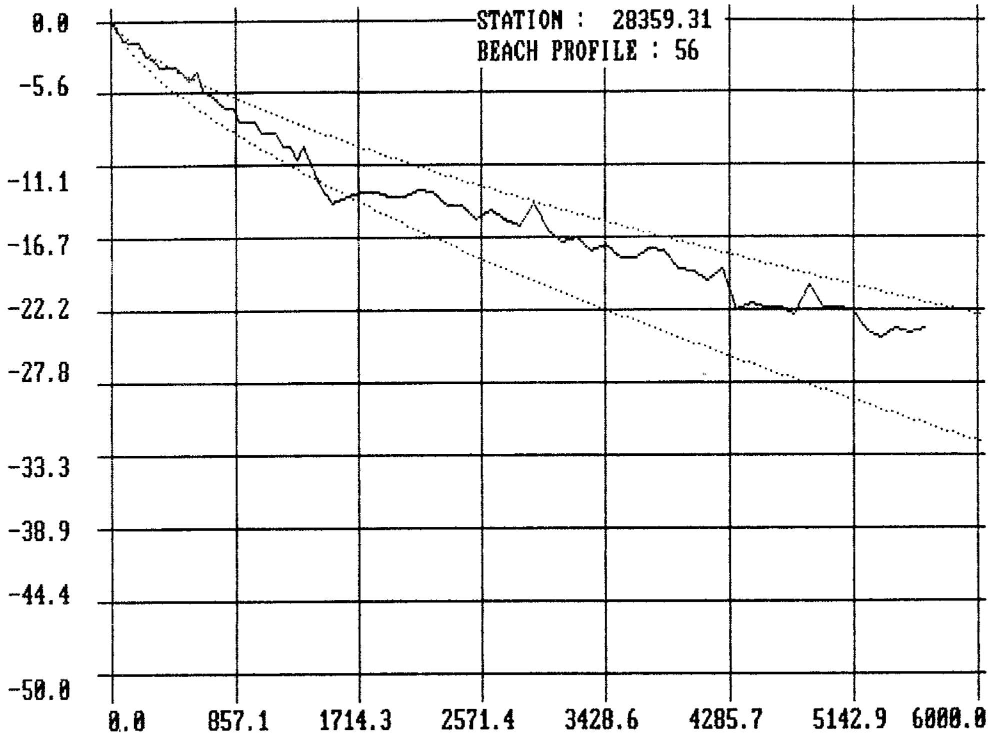
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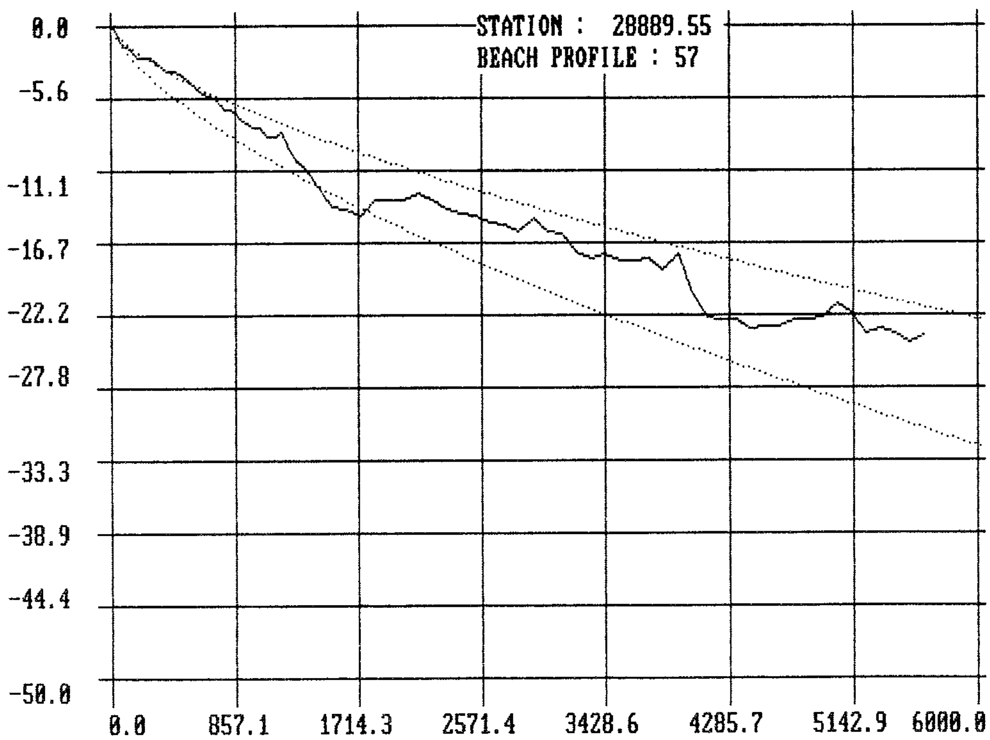
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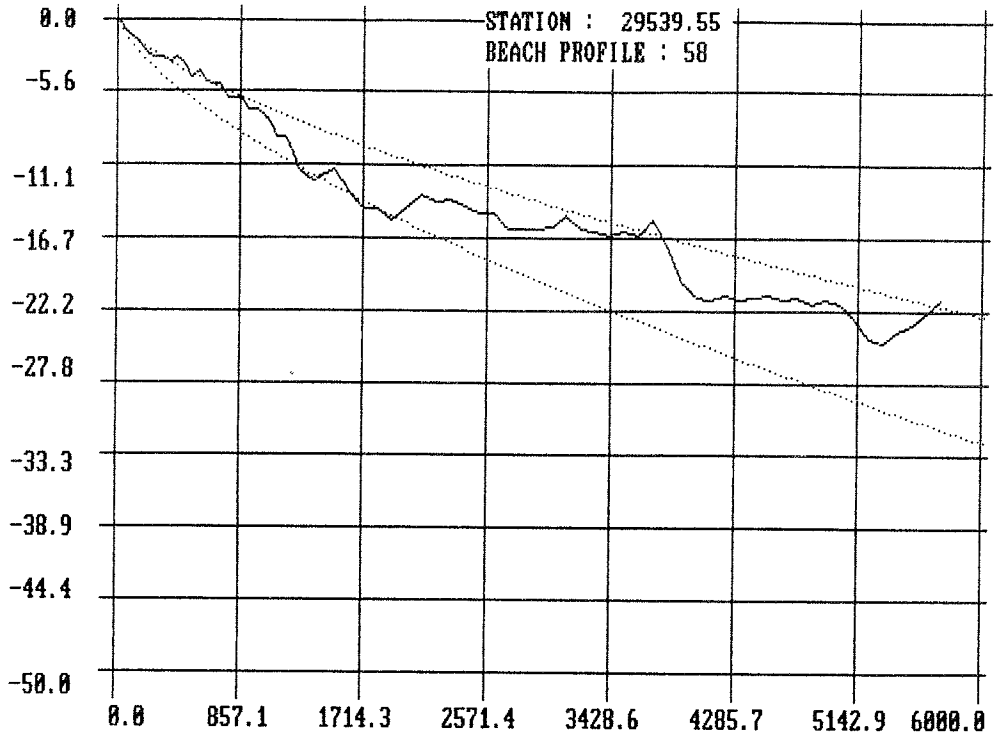
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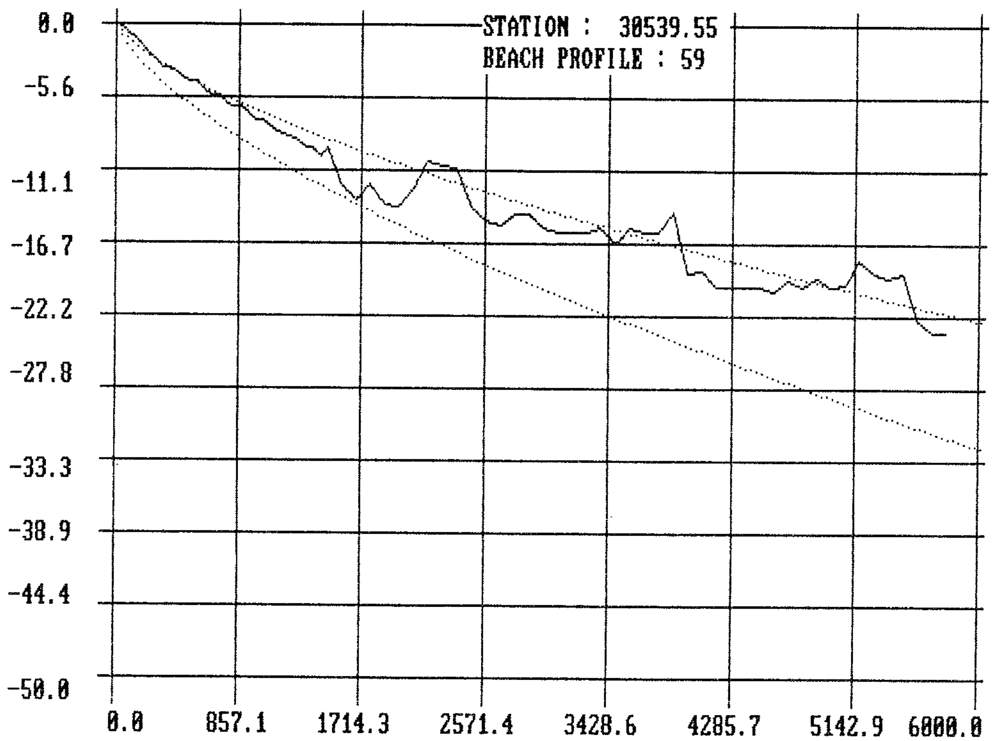
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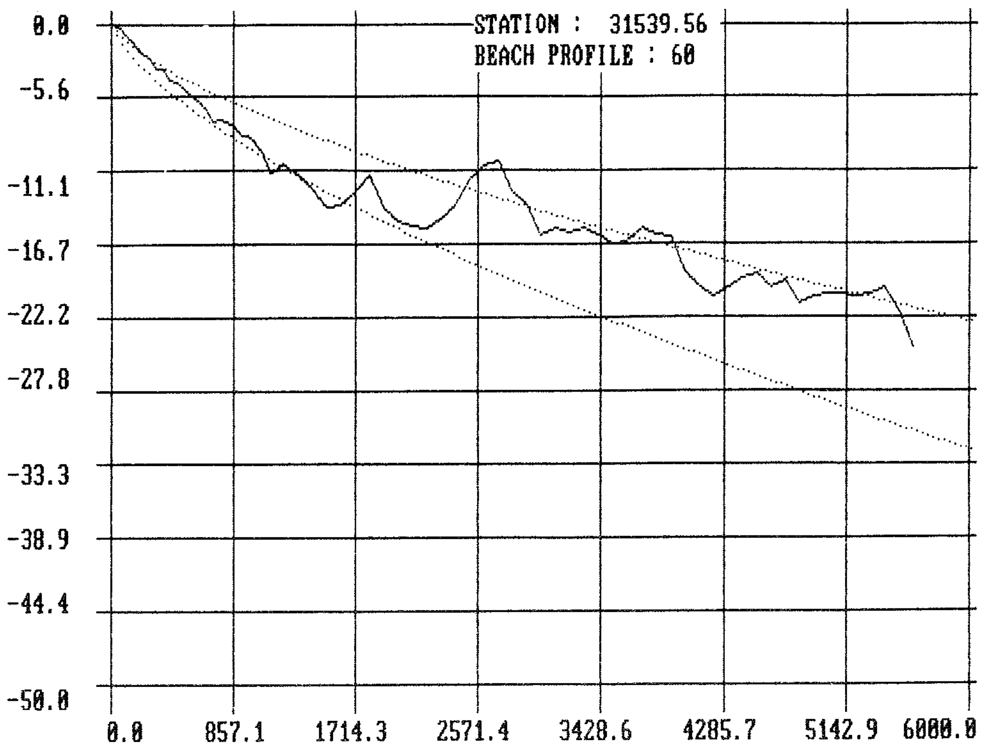
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857.1
1714.3
2571.4
3428.6
4285.7
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6000.0

APPENDIX E: Plan Formulation

THE NATURE OF THE PROBLEM

1. Maintenance of the Spit Road: The problem of wave overtopping and intermittent washouts along the Spit road has existed since its original construction in 1927. Other shoreline trends have also caused concern from time to time, and the immediate effects of the 1964 earthquake were dramatic by any measure. The roadway maintenance liability has remained the most consistent and long-term problem, presumably also the most expensive overall. It currently shows no sign of abating in spite of the wide variety of erosion control measures that have been constructed to date. These past measures have, in at least one instance (that of the vertical sheet-pile seawall), resulted in locally accelerated erosion (as indicated by the high waterline in Figure E-1) and increased overtopping. The plan formulation efforts undertaken in this study concentrated first on potential improvements to the storm protection of the roadway in the area where problems have been chronic (see Figure 3, main report). The long-term effect on the rest of the Spit of erosion control measures that might be placed in this trouble area was the first consideration in evaluating alternatives.

Figure E-1 - View toward the tip of Homer Spit, Alaska at high tide (August 1984)

2. Comprehensive Trends: The underlying cause of the highway maintenance problem has been revealed to be a deficit longshore sediment supply which occurs in the area of immediate concern. This implies that the problem could both accelerate (occur more frequently) and extend itself along the Spit if this cause is not addressed directly by future erosion control measures. The tip of the Spit, aside from the drastic immediate effects of the 1964 earthquake, appears to have been in a state of high-energy equilibrium for many decades. This metastable condition could be easily upset by a disruption in the sediment supply to the tip of the Spit, resulting in rapid shoreline retreat. The tip of the Spit now appears to recieve a large portion of its sediment supply from the southwestern shore of the Spit at the cost of erosion in the vicinity of the roadway maintenance problem. This material is almost all lost at the tip to deep water or to the Archimandritof Shoals, according to previous investigators and to the tentative conclusions of this investigation. The wave and tidal energy focused at the tip of the Spit would act quickly to erode this valuable shoreline if the sediment supply were reduced such that it no longer balanced the local sediment transport potential. The present amount of quantitative data available does not allow a confident prediction of how fast this might happen, since the high energy area at the tip is separated from the roadway problems by about 2 miles. Presumably this 2 miles of shoreline would have to retreat a great deal before the tip of the Spit would begin washing away, but this is far from certain. Immediate solutions to the problems of the Spit Road must therefore be approached with extreme caution. Plan formulation efforts in this study sought to address the long-term stability of the entire Spit to the extent that the limited available data allowed.

3. Seismic Hazards: A number of subjective observations can be made on seismic risks to the Spit's developments based on review of the historical accounts of the 1964 earthquake effects. Foremost among these is the risk of submarine landslides at the tip where developments are now many times more dense and valuable than they were in 1964. The steep slopes of coarse noncohesive sediments known to extend out to deep water at the tip are now susceptible to failure in the same manner as apparently occurred on both sides of the tip in March 1964. The probability of further consolidation and associated subsidence caused by seismic accelerations remains siginificant at the tip where coarse noncohesive sediments probably predominate well back into the land mass. Seismic failure analyses were not performed for any proposed alternative erosion control measures in this investigation, but rubble-mound slopes of 1:1.5 were avoided with the risk of seismic failure in mind.

INITIAL EROSION CONTROL CONCEPTS

4. Concepts Considered: A set of general concepts for erosion control measures at Homer Spit was initially formulated, based on historical efforts at the Spit and at eroding shorelines elsewhere around the world. These concepts are discussed below in terms of how appropriate they might be, given the specific circumstances at Homer Spit.

a. Beach Groins: A beach groin is a structure built out from the beach, generally perpendicular to the contours, for the purpose of trapping sediments travelling in the longshore direction. Groins are most commonly built as impermeable barriers but can also be partially permeable or low-crested so as to allow some bypassing. They are not generally built to locally modify the wave climate, though they do provide moderate shelter for a short distance on their leeward side. Their principal disadvantage is the fact that the trapped beach material is denied to the shoreline downdrift of the groin. A short distance beyond the groin wave energy and sediment transport capacity increases to its natural level, and material which is not supplied through bypassing is picked up from the beach profile. A scallop of localized scour is common on the downdrift side of beach groins, but the starvation inevitably caused by these longshore barriers can be much more extensive. A sequence of groins originally buried with beach fill would have no effect at all as long as they remain buried. The loss of the beach fill exposing the groins would allow them to assume their typical disruption of longshore sediment transport. The area of immediate concern on Homer Spit is now suffering from longshore sediment starvation. A groin or system of groins would only result in further disruption of the continuity of longshore sediment transport. Beach fill covering a system of groins would prevent the groins from having any effect until erosion caused them to be exposed. Once exposed, they would begin to realize their typical adverse effects. The concept of erosion control with beach groins was eliminated from further consideration for the reasons stated above.

b. Offshore Breakwater: This alternative is designed to modify the wave climate by the construction of a barrier parallel to the beach some distance offshore. Wave energy inside the breakwater is greatly reduced, though the degree of reduction can be controlled somewhat by adjusting the length and crest elevation of the structure. The zone of artificially reduced sediment transport capacity accumulates material, sometimes to the extent that a tombolo is formed with a bridge of accreted beach material reaching all the way out to the breakwater. Offshore breakwaters are also barriers to longshore transport, whether or not a tombolo forms. They create an accumulation of sediment on their updrift side and a decrease of supply with attendant scour on the downdrift side in a manner analogous to beach groins. Offshore breakwaters were also eliminated from more detailed consideration for this reason. The possibility of an armored toe structure for a beach fill was briefly considered, which would initially be constructed as a very low-crested offshore breakwater. This variation was also dropped since it was felt that the difficult construction and associated expense would not greatly add to the effectiveness of a beach fill.

c. Protective Beach Fill: An artificial fill of borrowed material on the beach face performs more than one useful function. First, a supply of material to downdrift beaches is provided, thus temporarily halting scour at the site of the beach fill and some distance down the coast. The elevated bottom at the site of the beach fill also causes waves to break farther offshore, reducing the wave induced transport and other effects on the upper beach profile. The principal economic disadvantage is that a program of periodic renourishment is required. Adverse biological effects are minimal if the fill material has approximately the same characteristics as the natural beach material. The natural material is widely graded from fine sand to cobble-sized stones and chunks of coal, so similar fill material specifications resembling natural beach material should not be impossibly strict. A suitable borrow site could presumably be located. Homer Spit, at 59 deg north latitude, is not popular for bathing; so considerations related to the comfort of barefoot bathers are not pertinent. This concept was marked for more detailed investigation.

d. Scour Protection: This concept includes all the traditional options, such as seawalls and slope revetments, for artificially armoring the natural beach material such that hydraulic scour is precluded or greatly retarded. These measures are also usually designed to attenuate the adverse effects of wave overtopping on ground behind the beach, or the roadway in the case of the Homer Spit. Seawalls are generally rigid structures of concrete, wood, or steel sheet pile built at the upper limits of wave effects to reflect incident waves or wave runup and prevent scour and overtopping. Slope revetments are generally flexible mattresses of stone or concrete units which serve as hydraulically stable ballast above the natural beach material. A filter of gravel or geotechnical fabric is often used between the ballast and finer beach material. The upper beach material at Homer Spit is naturally quite coarse (medium sand to gravel and cobbles), so a filter might not be necessary if the ballast units are not too large. The existing 5,400 ft of quarrystone revetment is built of stones from 1 to 3 ft in nominal diameter and has required minimal maintenance in its approximate 20 years in place without any observed filtering features. The stability of this existing structure, though it was built above normal high tide levels, indicates a quarrystone revetment would be a constructible and effective means of extending scour protection along the roadway. Rigid seawalls (particularly vertical structures) were eliminated from further consideration due to the localized scour and increased overtopping which has followed construction of 800 ft of steel sheet pile along the Spit road. A revetment with a rough, flexible, and permeable slope which dissipates wave energy in turbulence and viscous losses was deemed worth more detailed consideration.

ALTERNATIVE 1 - REVETMENT EXTENSION WITH SCOUR BLANKET

5. General Concept: This alternative was chosen as the best plan for scour protection without any attempt to nourish the beach material. The existing beach would be armored to the maximum practical from further erosion by wave attack. Graded quarrystone was deemed the optimum choice of armor material due to the good experience with the existing revetment and the generally better confidence with which the performance can be predicted. The existing revetment, whose approximate specifications are listed in Table E-1, protects the beach above high tide from erosion and the roadway from excessive overtopping during storms with high waves and water levels. This storm protection was proposed to be extended 2,300 ft from BP 49A to BP 44. The additional 2,300 ft was felt to be necessary since the lower beach would continue to erode without nourishment and expose more and more of the upper beach toward the tip of the Spit to direct wave attack. This plan involved an additional feature which would provide scour protection for the toe of the revetment and most of the upper beach. A scour blanket of material sized to be stable without the wave attenuation of the existing broad low tide terrace would accomplish this task. This "hardening" of the upper beach would presumably preclude any undermining of the revetment but would not prevent the lower beach from assuming a concave upward shape without a low tide terrace. The upper beach would eventually recede until the toe of the revetment was undermined without any scour protection below the revetment. A more narrow scour

blanket, on the order of 10 to 20 ft in width, would provide immediate toe protection during stages of the tide when waves were breaking on the toe but would not prevent the larger scale undermining accompanying recession of the entire upper beach. The broad (100-ft-wide) scour blanket is therefore recommended at this point in the study until further data are available to estimate potential beach recession rates.

Table E-1 - Existing Rubble Revetment Characteristics

Length	5,400 ft (BP 49A - 59)
Average Crest Elevation	35.0 ft MLLW
Average Toe Elevation	17.5 ft MLLW
Average Slope	1:2
Material (by visual inspection)	Graded quarrystone, median size approx. 900 lb., max. size approx. 4,400 lb., cobble-sized minimum

6. Revetment Design Criteria: The design of detailed features for a rubble revetment was performed only to a preliminary extent in this investigation, in keeping with the current confidence in quantitative site conditions, particularly the wave climatology. A design condition comparable to a sea state slighty more severe than the worst on record was applied to test the presumption that the existing rubble revetment was a stable and cost-effective configuration. The most critical parameters, including water level, wave height, and wave period, were then tested for relative sensitivity. It was immediately apparent that the wave height would be limited by depth, thus the water level and wave period were the most sensitive parameters. The information necessary to quantitatively evaluate the long-term probability of these parameters was not available. A design water level of 23.3 ft MLLW was adopted, intended to account for both astronomical tide and storm surge, equivalent to the "estimated extreme high water level" from NOAA Tidal Bench Mark data (see Table 1, Main Report). This same water level was applied to the recent design of the Homer Harbor breakwater (NPA, 1981). Wave periods of 8, 9, 10, and 11 sec were then applied to estimate by various methods the wave setup and breaker heights that would be incident on a revetment with its toe at 18 ft MLLW. A deepwater wave height of 18 ft and period of 11 sec was estimated by the methods of Goda (1975) to cause a setup of about 2 ft at the shoreline, given a breaker zone bottom slope of 1:10. A conservative mean water level of 26 ft MLLW (or 8-ft toe depth) was used for further computations. This depth was found to be well inside the breaker zone during severe storms and thus beyond the verified limits of most breaker height prediction methods. A breaker height of 60 percent of this depth, or 5 ft, was finally chosen for stability and runup computations, in keeping with unpublished findings of the 1982 Atlantic Remote Sensing Land-Ocean Experiment (ARSLOE) experiment. These conditions were taken to represent an extremely rare combination of circumstances which would preclude underestimation of project costs at this preliminary stage.

7. Revetment Design Computations: The sizes of armor stone and the associated armor thicknesses were estimated for a range of seaward slopes according to the guidance of the SPM (1984) for graded quarrystone (riprap). These computations are summarized in Table E-2. Runup heights were estimated for a range of slopes, wave periods, and exceedance levels by the methods of Ahrens and McCartney (1975) and Andrew and Smith (1985). The runup computations are summarized in Table E-3. Overtopping rates were also estimated for a range of slopes, wave periods, and crest elevations by the methods of the SPM (1984) as summarized in Table E-4. These estimates used a linear equivalent deepwater wave height, given the wave periods indicated, and the runup values estimated in Table E-3. Overtopping estimates were also made by the methods of Goda (1971) and Jensen and Sorensen (1979) which yielded comparable results.

Table E-2 - Summary of Hudson Formula Computations

STRUCTURE SLOPE	ARMOR WEIGHT		MIN. CREST WIDTH		ARMOR THICKNESS		NO. PER UNIT AREA	
(cot)	(tn)	(m tn)	(ft)	(m)	(ft)	(m)	(sq yd)	(sq m)
1.50	0.80	0.72	6.4	1.9	4.3	1.3	2.50	3.00
1.75	0.68	0.62	6.1	1.8	4.0	1.2	2.78	3.33
2.00	0.60	0.54	5.8	1.8	3.9	1.2	3.03	3.64
2.25	0.53	0.48	5.6	1.7	3.7	1.1	3.28	3.94
2.50	0.48	0.43	5.4	1.6	3.6	1.1	3.52	4.22
2.75	0.43	0.39	5.2	1.6	3.5	1.1	3.75	4.50
3.00	0.40	0.36	5.1	1.5	3.4	1.0	3.97	4.77
3.25	0.37	0.33	4.9	1.5	3.3	1.0	4.19	5.03
3.50	0.34	0.31	4.8	1.5	3.2	1.0	4.41	5.29
3.75	0.32	0.29	4.7	1.4	3.1	1.0	4.61	5.53
4.00	0.30	0.27	4.6	1.4	3.1	0.9	4.82	5.78

Note: This table includes the following specifications for graded quarrystone: Armor unit weight = 165.0 lbs/cu ft (2,643 kg/cu m), wave height = 5.0 ft (1.5 m), stability coefficient = 2.2, layer coefficient = 1.00, and armor porosity = 37 percent.

8. Preliminary Choice of Revetment Features: A brief analysis of the potential erodability of the roadway shoulder and embankment material, assumed to be primarily sand and gravel, revealed that virtually any sustained overtopping could cause some erosion. Table E-4 shows that the 1:2 slope of the existing revetment and a crest elevation of 33 ft MLLW would experience no more than 5 cfm/lf in the worst of conditions simulated. This rate does not account for the added attenuation and erosion protection of a substantial crest width. A crest width of 6 ft and splash protection between the revetment and roadway surface were assumed to be adequate to prevent significant erosion in this severe condition. The 33-ft crest elevation would not obstruct the view of Cook Inlet from the existing road whose surface is at approximately 30 to 31 ft MLLW opposite the proposed revetment extension. The slope of 1:2 would require 1,200-lb median sized rock (see Table E-2), slightly larger than the median size of the existing revetment. An underlayer of 70- to 135-lb quarrystone would provide adequate support for the primary armor without requiring a filter on the natural coarse material of the upper beach. This material could be placed in an excavated trench behind the

Table E-3 - Summary of Runup Computations*

WAVE PERIOD (sec)	EXCEEDANCE (percent)	REVETMENT SLOPE 1:1.5	1:2.0	1:2.5	1:3.0
8	1.0	11.6	10.3	9.3	8.5
	10.0	8.7	7.8	7.1	6.6
	13.5	8.2	7.4	6.8	6.2
	33.3	6.4	5.8	5.3	4.9
	50.0	5.2	4.8	4.4	4.1
9	1.0	12.1	10.9	9.9	9.0
	10.0	9.0	8.2	7.5	6.9
	13.5	8.5	7.7	7.1	6.6
	33.3	6.6	6.0	5.6	5.2
	50.0	5.4	5.0	4.6	4.3
10	1.0	12.5	11.3	10.3	9.5
	10.0	9.3	8.5	7.8	7.3
	13.5	8.8	8.0	7.4	6.9
	33.3	6.7	6.2	5.8	5.4
	50.0	5.5	5.1	4.8	4.5
11	1.0	12.9	11.7	10.8	9.9
	10.0	9.5	8.8	8.1	7.6
	13.5	9.0	8.3	7.7	7.2
	33.3	6.9	6.4	6.0	5.6
	50.0	5.6	5.3	4.9	4.7
12	1.0	13.2	12.1	11.1	10.3
	10.0	9.8	9.0	8.4	7.8
	13.5	9.2	8.5	7.9	7.4
	33.3	7.0	6.6	6.2	5.8
	50.0	5.7	5.4	5.1	4.8

* Runup height in feet above mean water level.

Table E-4 - Summary of Overtopping Rate Computations*

WAVE PERIOD (sec)	WAVE HEIGHT (H_o') (ft)	CREST ELEVATION	REVETMENT SLOPE 1:1.5	1:2.0	1:2.5	1:3.0
11	3.7	35	0.0	0.0	0.0	0.0
		34	2.0	0.0	0.0	0.0
		33	11.0	5.0	1.0	0.0
		32	30.0	18.0	10.0	5.0
		31	62.0	45.0	31.0	21.0
10	3.9	35	0.0	0.0	0.0	0.0
		34	1.0	0.0	0.0	0.0
		33	11.0	3.0	0.0	0.0
		32	24.0	13.0	6.0	3.0
		31		36.0	24.0	15.0
9	4.1	35	0.0	0.0	0.0	0.0
		34	1.0	0.0	0.0	0.0
		33	6.0	1.0	0.0	0.0
		32	21.0	11.0	4.0	1.0
		31	-	33.0	20.0	12.0
8	4.3	35	0.0	0.0	0.0	0.0
		34	0.0	0.0	0.0	0.0
		33	4.0	0.0	0.0	0.0
		32	16.0	7.0	2.0	0.0
		31	-	24.0	13.0	7.0

* Overtopping rates are in cfm/lf (1 cfm = 0.02 cfs); crest elevation is in feet MLLW.

existing sheet-pile wall, where the the nominal armor thickness exceeds the clearance, as shown in Figure 11 of the main report. A conventional core arrangement is possible beyond the sheet pile to BP 46, as shown in Figure 12 of the main report.

9. Revetment Maintenance Requirements: The retreat of the existing low tide terrace would be accompanied by gradually increasing wave exposure which would probably cause some maintenance requirements. A conservative subjective estimate of the repairs that would be required include replacement of 10 percent of the primary armor at least once in a 50-year economic life, nominally at the 25th year. The construction and maintenance specifications and estimated material quantities are summarized in the main report.

10. Scour Blanket: The characteristics of the existing upper beach were investigated closely and found to include an average slope of 1:9.5 and an average toe elevation of 6.5 ft MLLW from BP 43 to 54. The average slope distance from the toe of the existing revetment and proposed extension was 101 ft. An assumed convex-upward profile was superimposed on a number of existing profiles, extending from the lower limit of the upper beach beneath the present low tide terrace to a smooth intersection with the "equilibrium profile" shape that exists below MLLW (see Appendix D). This eroded profile would involve recession of the low tide contour to within 100 to 200 ft of the present toe of the upper beach. The midtide depth at this toe would be about 5 ft. Depth-limited wave heights of 3 to 4 ft and a slope of 1:9 were applied in Hudson Formula computations to predict stable armor sizes ranging from 57-135 lb. The previously assumed gradation for the revetment underlayer (70-135 lb or 11-13 in.) was thus adopted for a scour blanket which would extend 100 ft downslope from the toe of the revetment, as shown in Figure 10 of the main report. The scour blanket would extend longshore from BP 56 beneath the existing revetment to the end of the extension at BP 44, or 5,600 ft.

11. Future Extension: The rate at which the existing low tide terrace will be sacrificed opposite and toward the tip of the Spit from the revetment cannot be reliably estimated at this time. It is reasonably certain that this will inevitably occur, however, without dramatic changes in the sediment supply to the Spit system such as caused by the 1964 earthquake. The recession of these beach profiles will ultimately bring the roadway in this area to similar wave exposure and attendant maintenance problems which now occur toward the mainland. A future 1,200-ft extension to BP 44 of the revetment and scour blanket was felt to be a likely requirement sometime during a 50-year economic life, subjectively scheduled at the 25th year in this preliminary analysis. This would coincide with the anticipated requirement to repair the original revetment and scour blanket. Future analyses should be performed to predict the response of the Spit to an extended revetment with a scour blanket in order to more accurately schedule repairs and future extensions.

ALTERNATIVE 2 - COMPOSITE BEACH FILL AND REVETMENT EXTENSION

12. General Concept: A beach fill is basically an in-kind replacement of beach material that has been locally eroded away. The fill material should, in most cases, closely resemble the natural beach material to minimize biological impacts and to provide a suitable supply of sediment to downdrift beaches. The configuration of the fill should resemble the profile of the beach in an equilibrium state, that is, before any dramatic erosion occurred.

This can usually be judged from adjacent beaches if historical profiles are not available. Such a configuration allows the beach to provide a natural degree of wave protection to upland areas without causing a significant discontinuity in the local coastal processes. The concept of a composite beach fill came from observations of the August 1984 beach profiles (BP 30 - 40) and related beach sample data toward the tip of the Spit from the area of immediate concern (BP 40 - 59). The upper half of the tidal zone was noted to be relatively steep, on the order of 1:8 to 1:10. The lower beach, slightly below the mean tide elevation, makes a relatively abrupt transition to flat slopes of 1:100 to 1:150, extending 500 to 700 ft out to within a foot or two of MLLW. This lower beach or low tide terrace has, in some cases, a slight concave upward profile forming a broad berm whose crest was about 800 ft off the highway centerline. This feature might be analogous to an offshore bar which is typical for many sandy beaches where the tidal range is much smaller. The upper beach is composed of coarse material, including an armor of gravel and cobbles. The lower beach is typically composed of much finer material, with median diameter around 0.3 to 0.4 mm. The composite fill concept involves placing finer material at a flat slope on the lower beach and coarser material on a steeper slope above.

13. Lower Fill Geometry: The characteristics of potential borrow materials were not known during the course of this study, so it was necessary to assume some basic borrow specifications in order to plan an effective beach fill cross section. The material along the southwest beach of Homer Spit is naturally coarse when compared to sandy beaches elsewhere. The biological impacts of placing a fill of coarse material, somewhat more coarse than natural, were therefore assumed to be minimal. A further assumption that borrow material could be obtained somewhat more uniform in size than the natural gradation would preclude any significant allowances for initial losses of fines. Initial losses would thus be confined to handling losses and minor sloughing or other localized temporary instabilities at the boundaries of the fill. This means that the placement configuration can essentially be that of configuration after adjustment from exposure to waves. An intersection slightly above the midtide level (9.5 ft MLLW) at 10 ft MLLW was chosen as the upper limit of the fill, and a flat slope down to a toe at MLLW (0.0 ft) 800 ft off the survey baseline along the highway centerline was chosen. No special measures were deemed to be necessary to protect this toe, since in many cases it intersected the existing (August 1984) profile. The extent of the fill was chosen to be from BP 42 to BP 56 (about 7,900 ft or 1-1/2 miles) which extends 100 to 200 ft beyond the obvious erosion and intersects natural profiles on both ends that closely resemble the configuration of the beach fill.

14. Functional Characteristics of the Lower Fill: This fill repairs the low tide terrace where it has been lost and provides material for reformation of a protective offshore bar. The uniform offset and elevation of the toe and the flat slope from a uniform elevation at the top of the fill will create essentially parallel contours all along the extent of the fill. This feature will partially correct the refractive lens effect of the broad scour hole that now exists, thus attenuating the apparent discontinuity in sediment transport potential that now occurs. The decreased depth, as with any beach fill, provides additional protection to the upper beach by causing waves to break farther offshore. The upper portion of this fill also provides a uniform foundation for an upper fill of coarser material.

15. Upper Fill Geometry and Function: The upper fill of coarse material, predominantly gravel with a significant fraction of cobble-sized material, was chosen to extend across the areas where the top of the existing storm berms had receded to within 100 ft of the roadway. This included BP 43 - 55 or about 6,400 ft (1.2 miles). A uniform slope of 1:15 was chosen, more shallow than the existing 1:8 to 1:10 slopes, to create a stable toe protection for the rubble revetment and to reduce runup elevations during midtide to lowtide. The top of the upper fill was chosen as 18 ft MLLW, approximately at mean higher high water (MHHW) and the toe of the existing revetment. Also this elevation is the approximate lower shoulder of the storm berms which exist farther down the beach (i.e. the upper break point of the natural 1:8 to 1:10 slopes). This fill would provide increased wave protection to the revetment and roadway by causing wave breaking farther offshore during high tide and storm surge conditions. The local scour at the vertical sheet pile would also be repaired.

16. Renourishment Requirements: The upper fill was considered to be more coarse, more uniform, and at a more stable slope than the natural upper beach material and thus effectively stable, requiring no renourishment. The lower fill would erode at some rate significantly less than the natural lower beach material. The actual erosion rate was not available without successive survey data, so the estimates of sediment transport capacity were applied to derive a lower fill loss rate by the methods of the SPM (1984). The longshore wave energy flux estimates for the natural material at the boundary of the fill, in the vicinity of BP 42, were averaged to yield 56.8 lb/sec. A "K" coefficient was then derived by the same methods applied to estimate the sediment transport rates for the natural material, using the following relation:

$$K = 0.265 \log(gH/V_f^2) - 0.53$$

where

K = the sediment transport coefficient of Equation 4-49 in the SPM (1984)

g = acceleration of gravity

H = breaker height

V_f = fall velocity of median size beach material

17. The assumption of H = 5 ft and 4 mm median size sand with a fall velocity of about 1 ft/sec leads to an estimated 54,506 cu yd transport potential for the fill material. The further assumption of a step function between this rate at low tide and zero transport at high tide, consistent with the approach for the previous analysis, yields an average transport rate of 27,300 cu yd/yr. Replacement of 100 percent of the lower fill (299,600 cu yd after initial losses) would thus be required every 11 years. The renourishment volume should include the same allowance for initial losses with a placement volume of 329,600 cu yd.

18. The Need for a Revetment Extension: The composite beach fill would directly address the existing beach erosion problem and significantly attenuate the wave energy causing overtopping onto the roadway during storm conditions.

The safety and integrity of the existing roadway would still be threatened, however, during the most severe storms where water levels could reach 4 to 5 ft above the top of the fill. The adverse reflective effects of the sheet-pile wall would still exist in these conditions, and the road could still be overtopped well beyond the sheet pile. Some means of additional storm protection for the road in these areas is needed. The existing rubble revetment north of the sheet pile appears to be quite effective, with characteristics as summarized in Table E-1. A rubble revetment, with the same basic specifications as Alternative 1, was chosen for storm protection beyond the existing revetment, from BP 46 to 49A (about 1,100 ft), with its toe at the top of the upper fill. BP 49A is the start of the sheet-pile wall, and BP 46 is the apparent existing limit of overtopping hazard to the road. This revetment was assumed to require negligible repair if the beach fill below is maintained in a timely manner. Figure 13 in the main report shows the revetment extension and upper and lower fills at the sheet pile. The specifications of Alternative 2, including fill volumes estimated by the average end area method with the aid of the Interactive Survey Reduction Program (ISRP) (Birkemeier, 1984) are also presented in the main report.

ALTERNATIVE 3 - UNIFORM BEACH FILL AND REVETMENT EXTENSION

19. General Concept: The lack of information on borrow material characteristics called for a second beach-fill alternative with minimal gradation requirements. The glacial till material typically available from upland gravel pits on the Kenai Peninsula, with a median size of at least 4 mm, was taken as the probable nature of fill material for this alternative. Such material is usually widely graded with large gravel and cobbles mixed with fine gravel and sand. Experience indicates that gravel pits in the area usually can be developed to produce negligible amounts of silt and clay. A single fillet of this fill placed from the high tide level to a point well out on the low tide terrace would quickly adjust to wave exposure by sorting in the onshore-offshore direction. Coarser components would remain on the upper beach and finer material would spread out over the low tide terrace. This approach to beach fill is common, since the choice of borrow areas is often restricted in developed coastal areas.

20. Fill Geometry and Function: An 18-ft MLLW top of fill elevation was chosen for this alternative to assure increased protection from the toe of the revetment down the full extent of the upper beach. Experimentation with various toe elevations and offsets led to a choice of 3 ft MLLW elevation 500 ft off the roadway centerline. This configuration involved an estimated 350,000 cu yd (including a 10 percent allowance for initial losses), slightly more volume than the lower fill in Alternative 2. The longshore extent was chosen to be the same 7,900 ft from BP 42 - 56. The protection from loss of natural beach material and direct wave effects on the upper beach and revetment would be somewhat less with this alternative since its adjusted configuration would not decrease depths as much as the more initially stable lower and upper fills of Alternative 2. The exact difference in protection would manifest itself over a period of years and cannot be predicted without additional data and analyses on the nearshore wave climate and material response. The effectiveness of this alternative was at this preliminary planning stage assumed to be equivalent to that of Alternative 2, thus the two plans can currently be judged only on the basis of their relative initial placement and

renourishment cost.

21. Renourishment Requirements: The same loss rate estimated for the lower fill of Alternative 2 was assumed to apply to the portion of this fill that occupies the low tide terrace after initial adjustment. This portion was subjectively estimated to include 80 percent of the total volume after initial losses or 254,900 cu yd. Replacement of 100 percent of this volume would be necessary every 10 years. The total estimated renourishment volume, with 10 percent allowance for initial losses was 280,400 cu yd. A typical cross section of the beach-fill and revetment extension of Alternative 3 is shown in Figure 14 of the main report.

22. Revetment Extension: The specifications for revetment extension were chosen to be the same as for Alternative 2, with negligible maintenance requirements. The question of maintenance requires further study, not only from the perspective of refined wave climatology, but also from an optimization standpoint. A smaller armor size, requiring some periodic replacement, might prove more cost effective. The specifications for the uniform beach fill and revetment extension of Alternative 3 are summarized in the main report.

EVALUATION OF ALTERNATIVES

23. Preliminary Evaluation: The three alternatives proposed include two basic options: (a) beach nourishment across the areas now suffering from scour and (b) scour protection of the upper beach along the affected area. The first option directly addresses the underlying cause of the scour and beach recession by artificially adding sediment supply to counteract the effects of the the natural deficit. The second option is more traditional, involving placement of artificial armor which will prevent scour underneath. Both options were conceived to be equally effective in combating the immediate problems of roadway maintenance. The quantitative differences in their performance can only be subjectively estimated with existing data; therefore the principal evaluation criterion is at present the relative life-cycle costs of the alternative measures formulated above. A second beach-fill plan was formulated to accomodate field limitations on borrow material sources and to provide a more easily constructed alternative which might reduce the life-cycle cost of a beach fill.