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NINETEEN SEVENTEEN
HDR
NINETEEN NINETY TWO
75th Anniversary

December 10, 1992

Michael E. Wolski
State of Alaska
Village Safe Water
Department of Environmental Conservation
3601 C Street, Suite 310
Anchorage, Alaska 99503

Subject: Chefornak Water Resources

Dear Mike:

This letter report is the product of work outlined in my letter to you of August 31, 1992. The following pages show the results of the HDR Engineering, Inc. water resources reconnaissance for the City of Chefornak. In brief, Chefornak could use either ground water or surface water sources. However, wells must be properly built and operated to prevent producing brackish water. The only possible surface water sources for year round pumping appear to be the Kinia River and East Creek. Other surface sources could be pumped seasonally to supply fill-and-draw systems.

This letter begins with background, discusses the area's geology and hydrology, and finally makes recommendations and identifies additional data needs.

Purpose

The purpose of the current water resources availability project is the reconnaissance assessment of the availability and character of ground water and surface water sources suitable for development as community potable water supplies for the City of Chefornak. A suitable potable water supply is defined for this project as a source within at least 6,000 feet of the water treatment building and capable of supplying treatable water to:

1) A watering point system with an <u>annual</u> demand of 1.0 million gallons (or equivalent to a peak daily pumping rate of about 4 gpm), or
2) A washeteria system with an <u>annual</u> demand of a about 2.1 million gallons (or equivalent to a peak daily pumping rate of about 8 gpm), or
3) A fully piped community system with an <u>annual</u> demand of about 12.8 million gallons (or equivalent to a peak daily pumping rate of about 50 gpm).

A suitable source may be developed to supply a continuous pumping type system or a fill and draw type system. In addition to these minimum criteria, a ground water source exempt from Surface Water Treatment Rule (CFR Title 40 Part 141) regulations is preferred.

Specifically, the following were the resource inventory tasks:

1) Identifying and targeting potential ground water sources, including estimating:

- Aquifer depth and character,
- Range of aquifer production capacity, and
- Water quality, including potential for saltwater intrusion.

2) Identifying and targeting suitable surface water sources, particularly for supplying a fill-and-draw system, including discussion of:

- Limitations to source development, and
- Methods for maximizing annual water production from the source.

All work done in completing these tasks was performed using available data and information obtained from Village Safe Water (VSW) files. Much of this information has been compiled in an unpublished water resources summary completed by the Alaska Area Native Health Service, U.S. Public Health Service (PHS) for Chefornak in 1985; and a substantial portion of the available surface water data was collected during field work performed by PHS in 1984 and 1985. Regional data was obtained from other published sources. Additional interpretative and planimetric information was obtained through stereoscopic inspection of 1:60,000 color infrared (CIR) aerial photographs. No fieldwork was performed.

As the budget was very limited and only cursory analysis was requested, conclusions presented in this summary are suitable only for planning purposes and to provide guidance in further exploration and definition of suitable potable water supplies for Chefornak. Results presented are generally speculative and should be confirmed and refined in the field before design decisions are made.

The following narrative summarizes the findings of this resource inventory. Selected supporting data, data summary tables, and sketches including aerial photograph overlays, location maps, and descriptive sections are attached in draft format as requested. Formal presentation or report-ready copies of this supplementary material can be prepared upon request.

Area Geology

Chefornak is located on the south bank of the Kinia River. It is about 6 miles in a straight line and about 15 river miles from the coast bordering Etolin Strait. The village lies near the present coastal margin of the Yukon-Kuskokwim delta. At Chefornak this regional delta feature is comprised of thick accumulations of fluvial, deltaic, and eolian unconsolidated deposits of organic-rich silts, fine sands, and occasional fine gravelly sands. The unconsolidated sediments are greater than 400 feet thick at Bethel (Coonrad, 1957) and are known to exist to depths of at least 230 feet at Chefornak.

Volcanic rocks, possibly associated with the Kaltag Fault system to the north, form a series of low, barren, island-like bedrock hills south and north of Chefornak. Coonrad (1957) mapped basaltic flow rocks at Tern Mountain to the south of the community, and shows the rocks extending beneath the west side of the immediate village area (Attachment 1). These basaltic flow rocks have been interpreted to have been extruded, at least in part, synchronously with deposition of the unconsolidated delta sediments. Although most of the eruptive centers are older than the deltaic silts, volcanic activity has been reported within historic times (Hoare et. al., 1968; Coonrad, 1957) so that the more recent flows in the series may be interbedded with the unconsolidated delta deposits. Logs of wells drilled in the Chefornak vicinity suggest that the shallow basaltic rocks underlying the town may represent just such a sequence. Available well logs show at least 190 feet of unconsolidated deltaic sands and silts exist beneath the base of the thin basaltic rock layer encountered near the ground surface (Attachments 2, 3A, and 3B). Depth to additional interbedded basalt flow series or other bedrock beneath the unconsolidated sediments at Chefornak is not known.

The Yukon-Kuskokwim delta lies within a region of moderately thick to thin permafrost with maximum depth of perennially frozen ground at about 600 feet. However permafrost is also generally absent in close proximity to large water bodies (Ferrians, 1965; Williams, 1970). Limited information available for Chefornak suggests an active layer of about 3 feet in better drained lowland tundra areas with permafrost thickness of about 200 feet in areas away from the warming influence of the Kinia River or other large water bodies. Permafrost apparently thins rapidly adjacent to the river and is probably generally absent immediately beneath the river course. Logs of wells placed nearer the river (BIA, city, and church wells) show substantial thinning of permafrost compared to the series of high school wells placed at a greater distance from the influence of the Kinia River (Attachments 3 and 4). Evidence exists for the presence of "taliks" (perennially thawed zones within a permafrost mass) beneath the larger lakes within the immediate village vicinity, but these thawed zones probably do not completely penetrate the permafrost except beneath the largest and deepest lakes.

Climate

Chefornak has a subarctic maritime climate influenced by winter pack ice conditions. Climatological records for the National Weather Service Nunivak Station at Mekoryuk are assumed to be most representative of conditions at Chefornak (Attachment 5). Mean annual precipitation is about 15 inches. Predominant wind directions are northerly in the fall and winter and southerly in the summer (Attachment 6). Fall storms generate surges along the Etolin Strait which can raise stream levels of the Kinia River and contributing streams as far upstream as Chefornak, causing local flooding and impacting water quality.

Ground Water Hydrology

Chefornak is located within an area having both regional and local ground water recharge and discharge zones. Local recharge likely takes place along the upper slopes of Tern Mountain, with ground water discharging locally in the form of springs along the base of the mountain or into upper strata in the regional aquifer. The thick unconsolidated silts and sands underlying the community at depth are believed to be recharged regionally, however, by the larger lakes covering the delta lowlands at some distance to the northeast of the community.

All existing village wells are believed to tap the regional aquifer. Static water levels in the wells appear to generally exceed the adjacent river level, although data is contradictory. Static water levels of two of the high school wells were reported at about 100 and 240 feet below the ground surface at the time of drilling. However one of these wells (high school well #1) was apparently abandoned immediately and the static level in the other well was reported at 24 feet seven months after the initial, deeper, static water level report. Although neither of these data is considered reliable, the data do suggest insufficient time was allowed for stabilization of head in the wells and much higher static water levels than those reported may in fact exist.
Although data are inconclusive, it is believed that under natural conditions <u>regional</u> ground water flow in the vicinity of Chefornak is in fact discharging <u>from</u> the underlying silty soils <u>to</u> the Kinia River.

The deep static water levels reported for the high school wells and lagged correlation of well static water levels and river surface levels (Attachment 7) has been used to support the conclusion that some, and potentially substantial, surface water contribution occurs from the Kinia River to nearby wells. However the preponderance of hydrologic and water quality data does not appear to support this conclusion. As discussed above, the well static water levels may in fact be more typically above the average river level suggesting a more probable flow towards the river. Water quality data for the river and the wells (Attachments 8 and 9) also shows clear distinction between water from the different sources with the well water having much higher TDS and chloride concentrations and much lower iron concentrations than the samples collected from the river and its contributing streams. With well water quality data showing increases in TDS and chloride concentrations with time, but little apparent change in iron content, substantial inflow does not appear to be occurring from the Kinia River to the ground water aquifer tapped by the wells.

Quality of locally recharged ground water generated by infiltration along the upper slopes of Tern Mountain is likely to be substantially better than the regional ground water believed to be tapped by the existing wells. Locally recharged aquifers are likely to have substantially lower TDS and chloride concentrations although iron content may not be significantly different. However any locally recharged ground water aquifers present beneath Tern Mountain are not believed to have significant impact on ground water resources available within a radius of one mile from the village. Although some possibility exists of obtaining water of sufficient quantity and quality from locally recharged basaltic flow rock aquifers along the lower slopes of Tern Mountain, transmission distances could easily exceed 10,000 feet and would likely require performing geophysical explorations and drilling a number of exploratory holes to assess possible aquifer locations.

Water quality data for wells completed at Chefornak suggest that the aquifers tapped are within or near the brackish mixing zone between the freshwater regional aquifer and the saline ground water wedge extending inland from the coast. Gross estimation of the geometry and hydraulic properties of the regional aquifer and application of a simple model (Kashef, 1986) suggests the Chefornak area lies within an area subject to saltwater upconing (Attachment 10). Upconing may be a reasonable explanation for the increase in chloride and TDS concentrations reported over time for the BIA well while the nearby, and less heavily pumped, city well apparently did not experience similar water quality changes (Attachment 8).

Surface Water Hydrology

Surface water near Chefornak includes the Kinia River bounding the project area to the north; shallow lowland tundra lakes, ponds and small streams draining to the Kinia River; and springs reported at several locations along the south base of Tern Mountain and interpreted as occurring elsewhere along a broad band around the base of the mountain (Attachments 11 and 12).

Dall Lake and its principal tributary, the Chukwugwahlik River, form most of the approximately 900 square mile watershed of the Kinia River. The highest elevation in this basin does not exceed 80 feet, and the elevation of Dall Lake is approximately 15 feet. The Kinia River at Chefornak is about 1,000 feet wide and has been measured at about 9 feet deep. The river is believed to provide sufficient discharge year-round to meet minimum quantity criteria for either a continuously pumped or a fill-and-draw type community system at Chefornak. It is tidally influenced but its water quality is not believed to be significantly affected by seawater except during fall storm surges.

Other streams in the Chefornak project area (within 6,000 feet of the water treatment building) drain small basins and thaw lakes located on a low, wet tundra surface underlain by shallow permafrost typical of the Yukon-Kuskokwim delta. A total of 4 of these local watersheds were identified and named for the purposes of this summary as: West Creek, WS ("watershed") A, WS B, and East Creek. Lakes present within these basins which were studied in the past or were believed to represent a potential water source for the village were also identified (Attachments 11 and 12).

These local watersheds display characteristics typical of lowland tundra basins in permafrost regions. The lakes are anticipated to be, with few exceptions, small and very shallow

(Attachment 13). Most will probably freeze to the bottom during the average winter and will have little under-ice water storage available at the end of winter. Stream flows from the local Chefornak basins are also likely to cease or be lost to icings in the latter part of the winter. East Creek may, however, vary somewhat from streams draining the other basins. A substantial portion of this stream's flow is derived from the north flank of Tern Mountain, possibly including ground water discharged as springs at the base of the mountain. Spring discharges along with discharges from the numerous lakes and ponds within this basin may provide sufficient runoff to maintain some low flow throughout the winter.

Summer stream flows on the average will be continuous in all the basins, although highly variable in rate. Flows will be rapidly responsive to snowmelt events and, depending on size and number of contributing lakes and ponds, somewhat less "flashy" during rainfall runoff events. Between each storm runoff event, flows will drop rapidly to very low base flow rates maintained by reservoir storage from any contributing lakes and ponds and by shallow ground water from the saturated tundra surface.

Estimated mean annual and monthly flows for streams draining the 4 watersheds are summarized in Attachments 14 and 15. Annual average flow estimates were based on regional observations (Balding, 1976) and mean monthly flow estimates were extrapolated directly using the gaging record of a basin with similar climatological conditions (Crater Creek near Nome, Alaska). In fact, the estimated mean monthly flow values shown in Attachment 15 are likely higher than the average monthly flows actually experienced at the Chefornak basins. The gaged basin at Crater Creek has a considerably higher average basin elevation than that of any of the Chefornak basins resulting in a possible overestimation of flows at Chefornak of 1.5 to 2 times the actual flows. These estimates suggest that only East Creek (or the Kinia River) may be suitable for development as a year-round potable water source for the community.

Estimates were also generated and tabulated of total annual available surface water quantities, both from snowmelt and rainfall runoff, at nine selected lakes (Attachment 13) within the Chefornak basins. Volume estimates are based on the watershed area contributing to each lake, and on <u>total</u> estimated relocated precipitation for drifted snow contributions (Tabler et. al., 1990). Total equivalent water as snow is probably overestimated because fetch was only grossly estimated and snow transport <u>out</u> of each basin was not included in the estimation. Rainfall runoff is also probably overestimated for those basins with a substantial percentage of the total watershed area in ponds and lakes. Evaporation losses for those basins are likely to be much larger than those used in calculating the values shown in Attachment 13. Also note that these estimated water volumes do not represent stored water but only total runoff. Storage either within a lake basin or in tanks would have to be developed to meet the continuous daily water needs of the community.

Water quality within the Chefornak basins will vary substantially seasonally and by location in the basin. (Because locations of all potential human contaminant sources--garbage dumps, sewage disposal sites, etc.--were not known, none of the basins discussed in this summary were assessed on this basis. Obviously where these contaminant sources impact the watersheds, the basin boundaries should be appropriately redefined.)

Lake and stream water that is available in the middle of winter is likely to be of very poor quality, substantially deteriorated from summer conditions (note water quality data for the "Weir Stream" collected on 4/27/85, Attachment 9). Although no supporting data exists, the winter water quality of the Kinia River and East Creek may differ significantly, however, from that encountered within the other smaller Chefornak basins. Although the dissolved solids content of the Kinia River may not be as heavily influenced by increasing ice cover as the local streams and ponds, river water quality may become significantly impacted by tidal flows as river freshwater flows decrease throughout the winter. East Creek may also experience poorer winter water quality as a result of tidal effect, especially near its mouth, but water quality may also be positively influenced as a result of spring discharge at the creek's headwaters.

Water quality will also vary predictably during the spring and summer months although all summer sources will require, at minimum, some treatment to remove iron and THM precursors. Early in a snowmelt event, water quality will be generally good but will typically rapidly deteriorate as snowmelt progresses. Particulate organic content and total dissolved solids (noticeably iron) rapidly increases in the latter half of the annual snowmelt event as the tundra mat begins to thaw and bottom-fast pond and lake ice is loosened. Following spring breakup, the quality of stream base flows will improve somewhat, but storm event flood flows will be characterized by marked increases in turbidity (represented mostly by particulate organic matter). Lake water may also become extremely turbid during windy periods when lake bottom sediments are mixed into the water column. Finally, fall storm surges may result in brackish water in the Kinia River and along the lower reaches of its larger contributing streams (especially East Creek).

Summary and Recommendations

Potential community water sources at Chefornak include ground water produced from regional aquifers and surface water.

The ground water aquifer at Chefornak is confined by permafrost ranging in thickness from about 100 to 240 feet. The most probable aquifer materials to exist within the 6,000 foot project radius consist of fine sand and silty sand. These are likely recharged by regional ground water flow. Infiltration from the Kinia River to nearby wells is not likely except in an improperly or specially designed well. Aquifers in basaltic flow rocks recharged by infiltration along the upper slopes of Tern Mountain may exist to the south of the village but are not likely to be encountered at distances of less than 6,000 feet from the community.

Yields from the silty sand aquifers near the village are anticipated to range from 5 to 50 gpm. However these aquifers are within the brackish mixing zone and upconing of saline or brackish water may occur at the higher production rates. Based on gross approximations of aquifer properties, drawdowns in wells should not fall below elevations of 2.5 to 5 feet above sea level if upconing is to be prevented. Additionally, wells substantially deeper than the base of the permafrost have increasing probability of encountering saline water. Before additional well construction is done at Chefornak, careful aquifer tests should be performed using existing wells to provide a basis for reliable estimates of long term yields and water quality characteristics from these aquifers.

A variety of surface water sources exist at Chefornak including the Kinia River and local streams and lakes. However it is likely that only the Kinia River and East Creek have potential for providing a supply suitable for continuous year-round pumping. The assumption that East Creek flows during winter would be adequate for pumping is speculative and must be confirmed. These two sources may also experience water quality problems during fall storm surges and winter low flow periods. Seasonal water quality sampling of both sources should be performed to assess probable conditions. If East Creek proves to be otherwise suitable, impacts from storm surges and Kinia River flows may be reduced by construction of a dike across the lower reach of the creek.

Although stream flows from local Chefornak basins may occur throughout the early part of the winter, water quality is likely to deteriorate and flows cease by late winter. The lakes all appear to be shallow and are likely to freeze to the bottom or near bottom by the end of the winter with associated decreases in water quality. However all the basins can supply adequate annual or seasonal quantities of water assuming sufficient water storage for the selected fill-and-draw design is developed or built and collector snow fencing is constructed to enhance basin precipitation. Snow depth data from the end of winter and wind data should be collected for any selected basin and its associated fetch to allow accurate estimation of available relocated snow.

Water from the lakes and small stream flows will typically have high iron content and turbidity (i.e. particulate organics) but will show predictable variations in these parameters. During early snowmelt water quality will be at its best. It will be at its worst when bottom-fast ice is released and during peak flows resulting from rainfall runoff. Lake intakes should also be located to protect against bottom sediment stirring during high wind periods.

Although gross cost considerations (not assessed in this summary) may eliminate some alternative sources, the data available for our review does not allow outright elimination of any of the sources discussed in this summary. Therefore we recommend some additional data be collected to allow refinement of source characteristics. Depending on preliminary system cost estimations, these data could include:

- Water quality and flow data for the Kinia River and East Creek collected periodically throughout the winter.

- Late winter water quality and flow measurements at other targeted small basin streams.

- Snow depth data collected at the end of the winter for fetch and watershed areas for alternative lake basins.

- Wind data collected during the winter near the community.

- Reconnaissance and collection of water quality and flow data for any springs along the north base of Tern Mountain.

- Aquifer testing and water quality data collected from one or more Chefornak wells.

We hope that this summary and reconnaissance analysis of available water resources at Chefornak will be useful in guiding further planning for development of a community water supply. If you wish, we would be happy to further refine these preliminary estimates, develop data collection plans, collect additional data, or assist you in performing these tasks. Please let me know if we can be of any further assistance.

Sincerely,

HDR ENGINEERING, INC.

Scott R. Wheaton
Engineering Geologist

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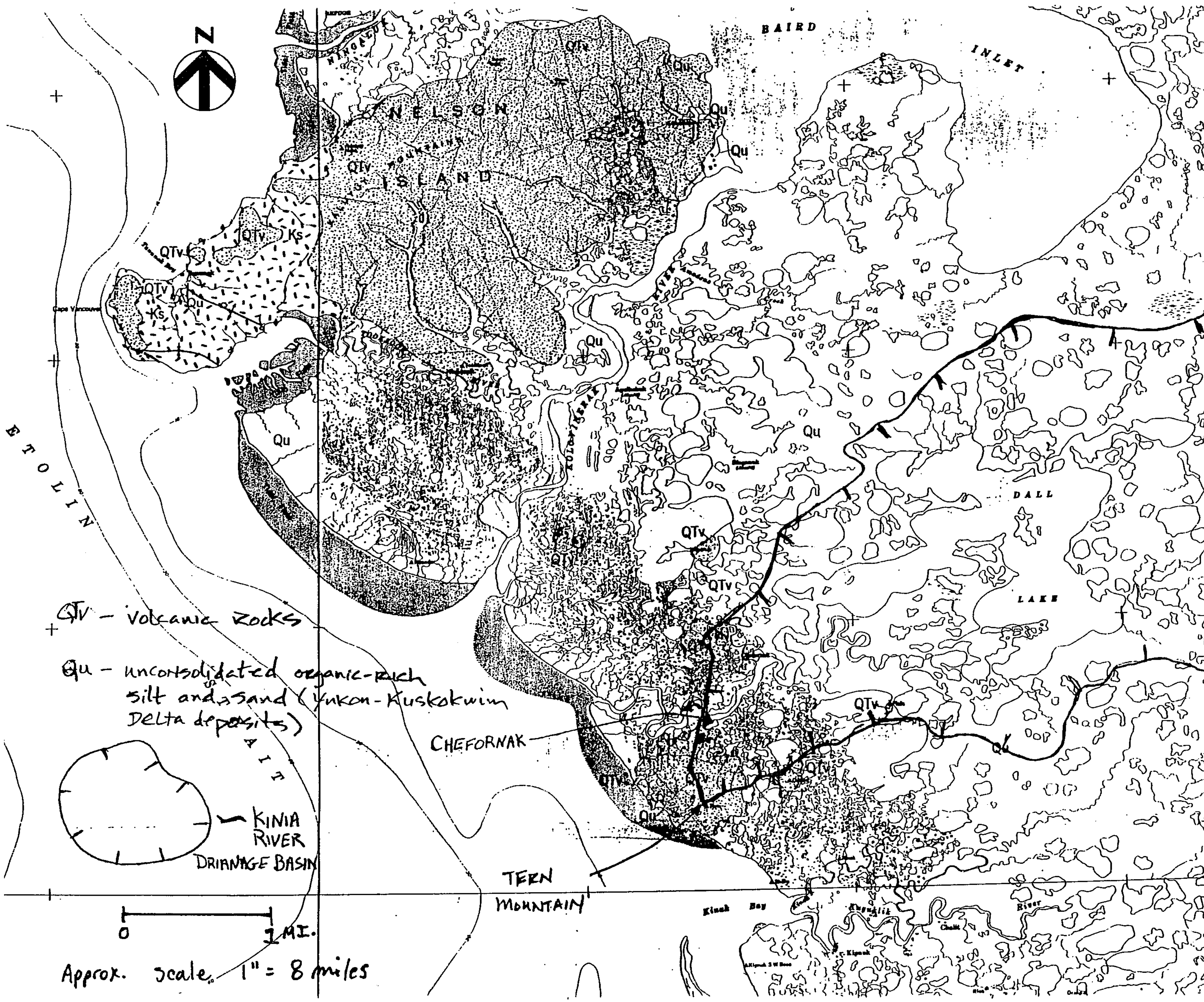
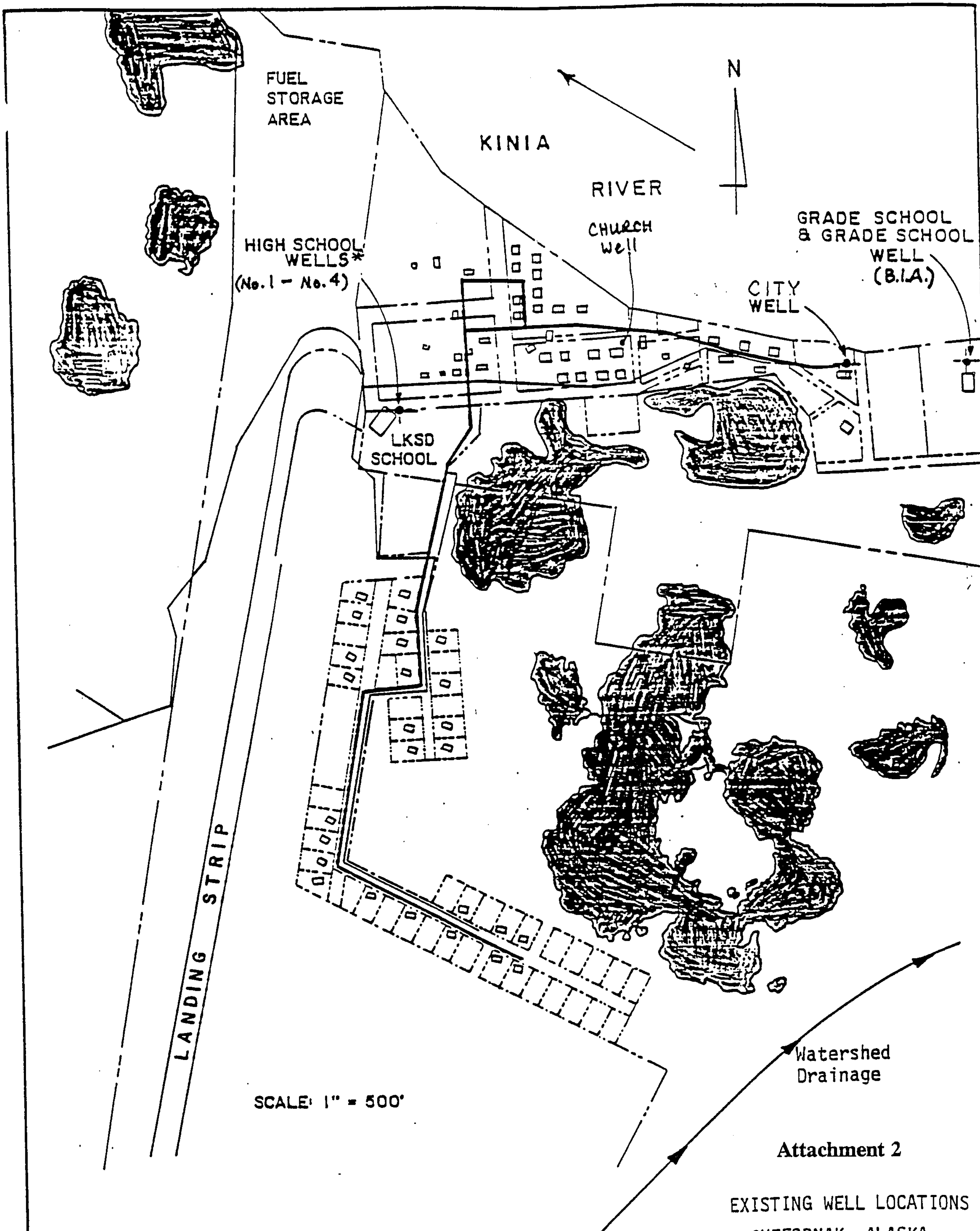
Attachments

N:07078.005:2:D3

Attachment 1





Attachment 2

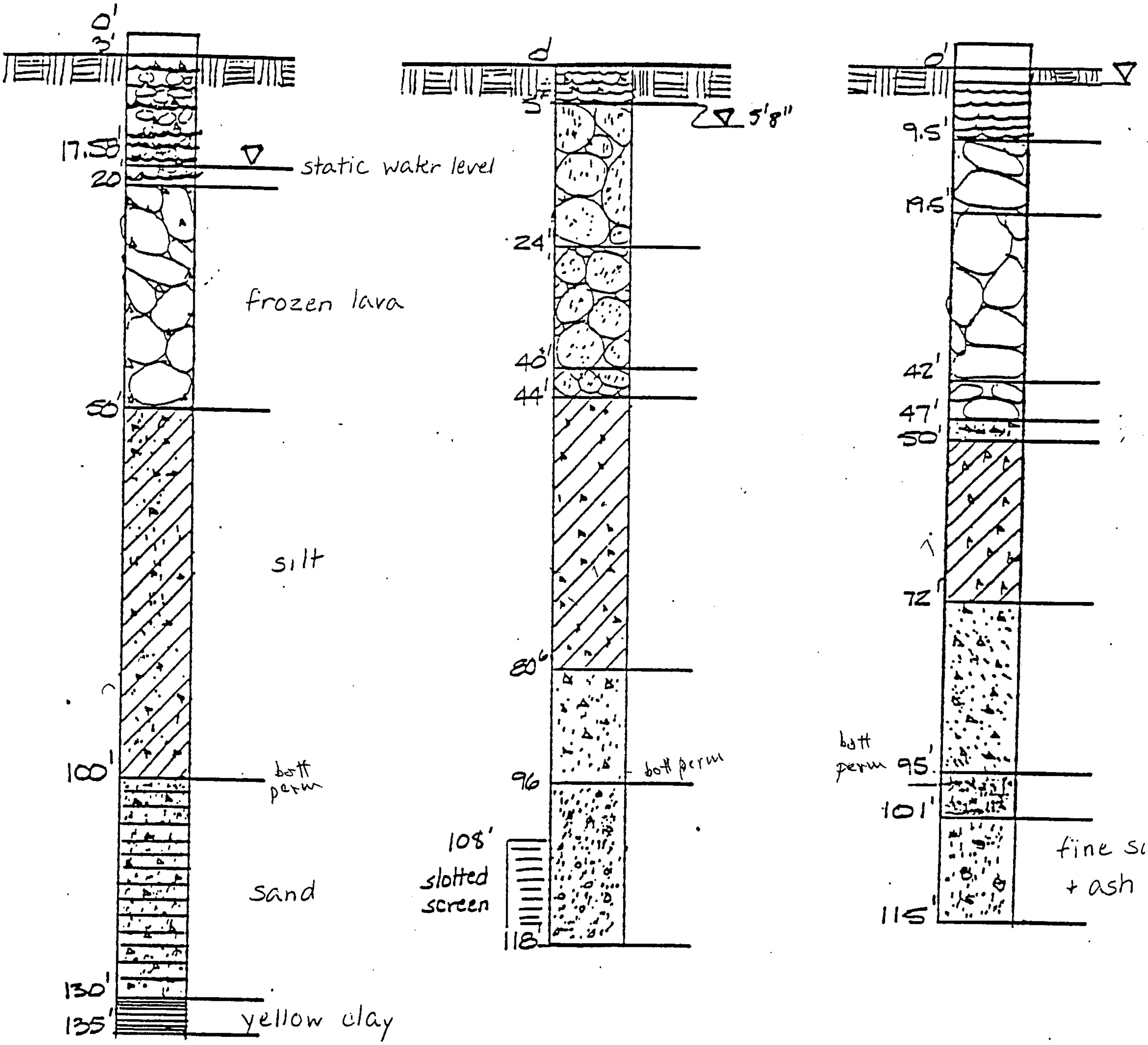
EXISTING WELL LOCATIONS
CHEFORNAK, ALASKA

*Exact location of 4 High Scholl wells is not currently known.

Attachment 3A

Chefornak Well Logs

#1 CHURCH WELL | #2 CITY WELL | #3 BIA WELL

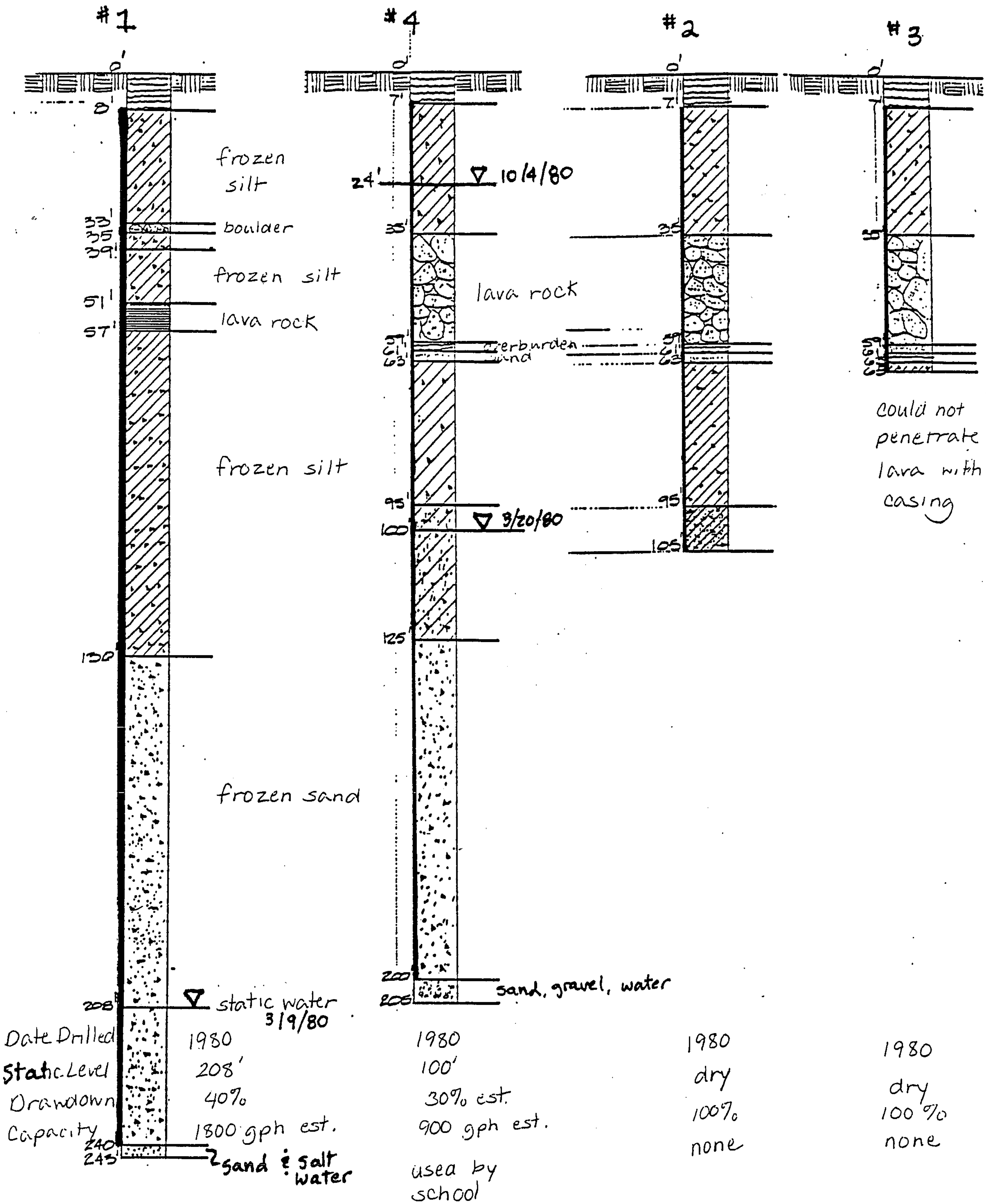


	#1	#2	#3
Date Drilled:	1964	1965	1976
Static Level:	~~17.6'~~ 17.6'	5.8'	2'
Drawdown:	3 gpm	14.4'	39'
Capacity:	1.3 gpm	9 gpm	22 gpm

Attachment 3B

Chefornak

High School Wells



ATTACHMENT 4

WELL CHARACTERISTICS
CHEFORNAK, ALASKA

WELL	DATE DRILLED	TOTAL DEPTH (FT)	DEPTH TO FIRST WATER (FT)	YIELD[1] (GPM)	DEPTH OF PERMA -FROST	STATIC WATER LEVEL (FT)	BOTTOM OF CASING (FT)	PRODUCTION INTERVAL (FT)	AQUIFER DEPTH (FT)
High School Wells:									
#1	3/9/80	243	240	30	8-240	208	?	240-243	240-243
#2	3/11/80	105	Dry	Dry	>105 7-105	Dry	35	---	---
#3	3/13/80	60	Dry	Dry	>65 7-65	Dry	54	---	---
#4	3/20/80	205	200	15	7-200	100/24[2]	148	200-205	200-205
City Well	5/16/65	118	96	9	45-95	5	108	108-118	95-118
BIA Well	1976	115[3]	95	22	47-95	2	95	95-115	95-101
Church Well	7/29/64	135	100	1.3	0-100	17	112	112-130	100-130

[1] Yields estimated at time of drilling.
[2] At time of drilling/7 months after drilling.
[3] Drilled to 132 feet.

N:07078.005:2:D2

ATTACHMENT 5

SUMMARY OF CLIMATOLOGICAL DATA
NUNIVAK STATION AT MEKORYUK, ALASKA

(Period of record: 1923-'73)

WATER-SHED	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Mean Precip. (in.)	0.89	0.95	1.10	0.77	0.59	0.76	1.38	2.24	2.17	1.96	1.29	1.06	15.14
Mean Snowfall (in.)	10.6	7.6	8.6	3.6	3.1	1.2	0	0	0.6	5.5	8.8	9.1	58.6
Mean Temp. (°F)	11.6	10.2	13.5	22.7	33.4	42.4	48.3	49.6	45.3	34.6	25.0	13.7	29.2

Job No. No.

Computation

HDR

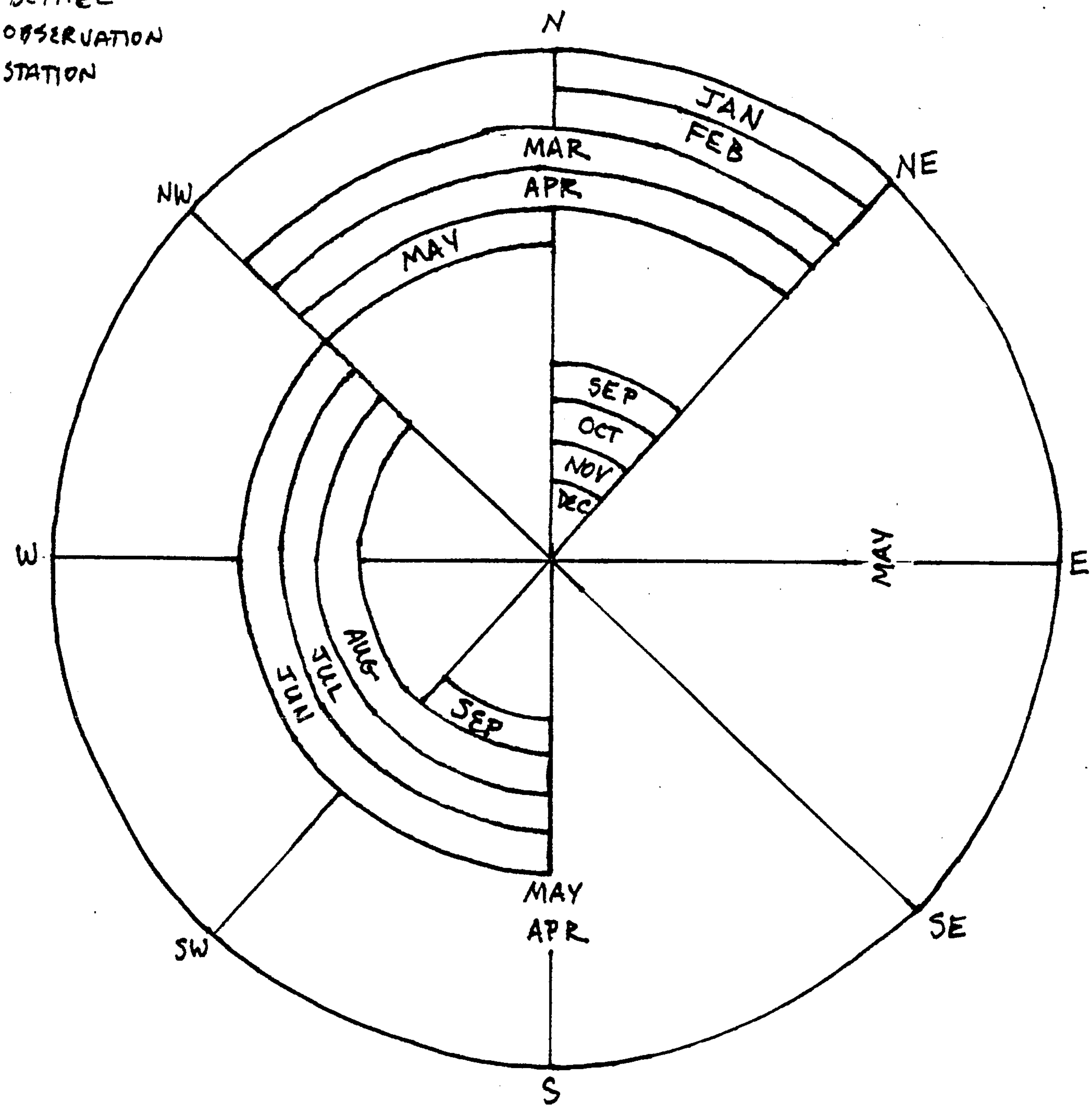
Project CHEFORNAK | Computed | Date

Subject | Checked

Task PREDOMINANT WIND DIRECTION by MONTH | Sheet

Attachment 6

BETHEL
OBSERVATION
STATION



SOURCE: CLIMATIC ATLAS OF THE OUTER CONTINENTAL SHELF WATERS & COASTAL REGIONS OF ALASKA. VOL. II - BERING SEA

CHEFORNAK – WATER QUALITY AT HIGH TIDE – KINIA RIVER

THE FOLLOWING READINGS WERE TAKEN ON 9/12/85 APPROXIMATELY 1 HOUR BEFORE HIGH TIDE. SIXTY FEET OFFSHORE BY THE PUMPHOUSE ON THE KINIA RIVER,

PROBE WAS SET AT 1 FOOT ON SOUNDING ROD

DEPTH (FEET)	WATER TEMPERATURE °C	SALINITY PPT	CONDUCTIVITY MS/M	TEMP. CORR. CONDUCTIVITY
7.8	8°	0	235	155
7.0	8°	0	240	158
6.0	8°	0	240	158
5.0	8°	0	240	158
4.0	8°	0	240	158
3.0	8°	0	240	158
2.0	8°	0	240	158

was this bottom of river

WATER SAMPLE TAKEN AT THIS TIME HAD A CONDUCTIVITY OF 200 WHEN TESTED ON THE PUMPHOUSE METER,

METER USED IN RIVER WAS A YELLOW SPRINGS INSTRUMENT CO, SCT METER,

Attachment 7

ATTACHMENT 8

SELECTED WELL WATER QUALITY RESULTS
CHEFORNAK, ALASKA

WELL	DATE	TDS (mg/l)	CHLORIDE (mg/l)	SPECIFIC CONDUCTANCE	TOTAL IRON (mg/l)	MAGNESIUM (mg/l)	HARD-NESS (mg/l)
BIA Well	10/5/66	541	112	924	0.78	14	100
BIA Well	2/4/71	634	175	1,070	0.5	23	127
BIA Well	3/8/78	1,060	---	1,310	0.62	35	149
BIA Well	9/5/79	---	400	1,400	0.6	31	---
City Well	9/5/75	486	102	738	0.23	16	70
City Well	1/20/78	445	130	750	0.3	14	87
City Well	9/5/79	---	168	800	0.3	15.9	---
City Well	5/22/81	415	111	840	0.22	12	62
City Well	12/21/82	500	130	840	0.18	12	63
City Well	9/1/85	457	122	750	0.5	13	67

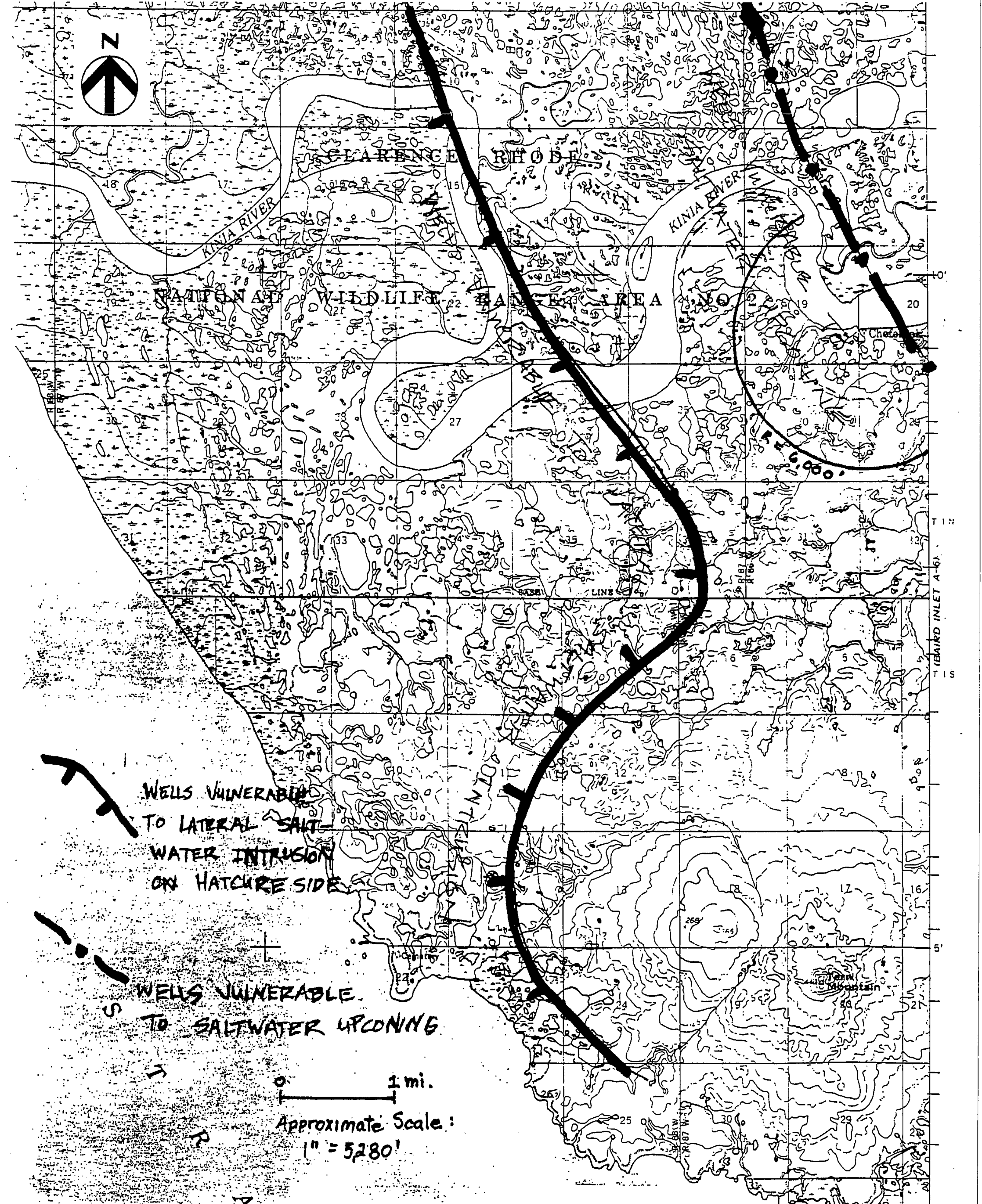
Note: In 1983, "all-weather" watering points were connected to the city well.

ATTACHMENT 9

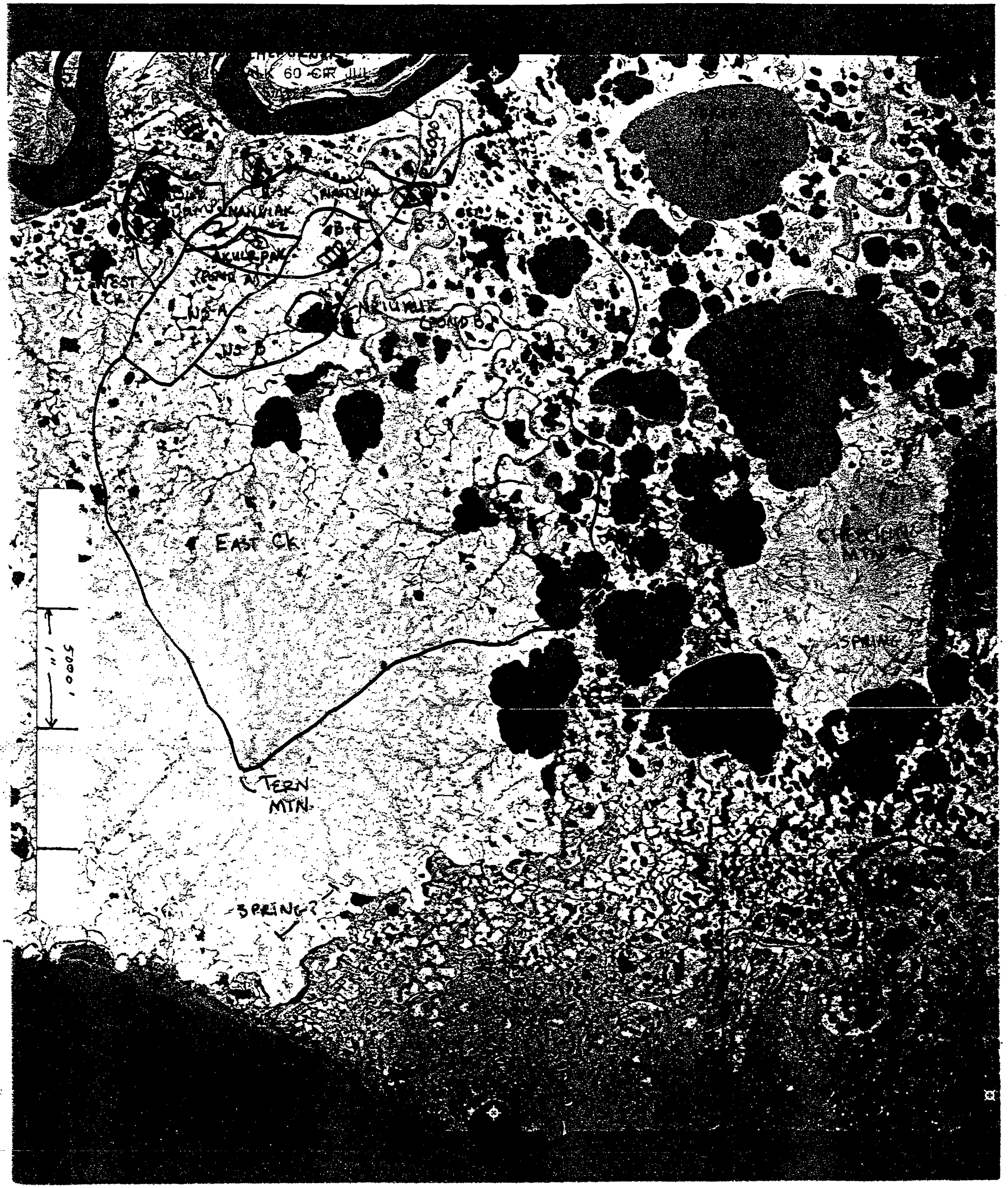
SELECTED SURFACE WATER QUALITY RESULTS
CHEFORNAK, ALASKA

SITE	SAMPLE DATE	TDS (mg/l)	CHLORIDE (mg/l)	SPECIFIC CONDUCTANCE (umhos/cm)	TOTAL IRON (mg/l)	HARDNESS (mg/l)
Pond 200' SW of Runway	7/25/84	21	5	35	2.7	15.0
Stream 2,000' SE of Runway	7/9/85	16	2	22	1.3	4.1
Weir Stream	4/27/85	97	15	120	37.0	34.0
Kinia River	9/12/85	175	76	290	7.8	29.0
Old Lake	8/18/91	66	22	120	1.8	21.0
Pond B	8/18/91	89	36	175	4.0	14.0
Pond B Stream	8/18/91	20	3.9	37	1.6	9.1
East Creek	9/17/91	192	74	325	2.8	33.0

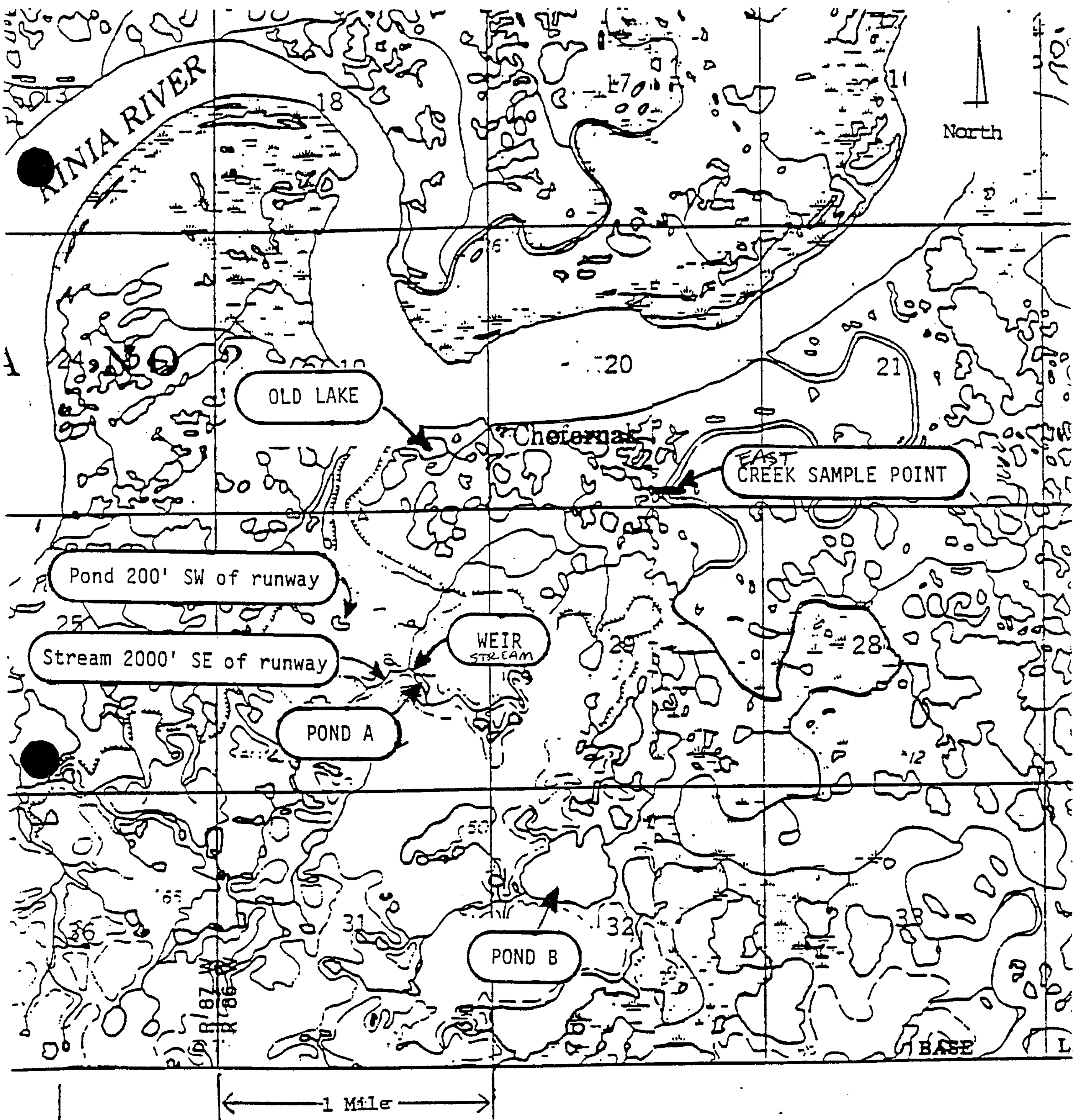
Notes: Wier stream sample taken under ice. Kinia River sample taken at high tide.

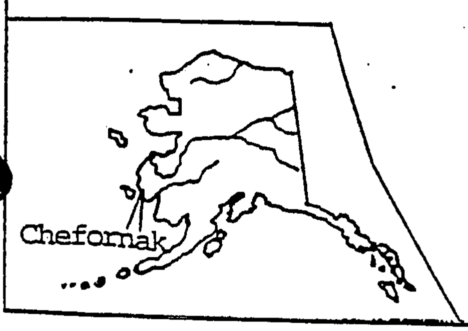


Attachment 10



60 CIR JUL
NANUVIAK
B-3
B-4
B-5
AKULEPAK
(POND A)
WEST CK
US A
US B
NIGIUKLUK
(POND B)
East Ck.
TERN MTN
SPRING?
SPRING
5000'





Attachment 12

Water Sample Locations

CHEFORNAK AND
SURROUNDING AREA

ATTACHMENT 13

LAKES
CHEFORNAK, ALASKA

LAKE NAME	BASIN AREA (Acre)	LAKE AREA (Acre)	LAKE DEPTH (Ft)	LAKE VOLUME (Gal)	FETCH[1] (Ft)	SNOW[3] (Gallons)			RAIN[4] (Gallons)
						BASIN[1]	DRIFTED[2]	TOTAL	BASIN
Akulrpak (Pond A)	525	1.1	4.8	1,725,000	5,000	123,493,000	15,776,000	139,269,000	53,170,500
Nriukuk (Pond B)	355	47	1.8	27,638,000	8,000	83,505,000	3,285,000	86,790,000	35,953,500
Nanviak #1	18	1.7	3.7	2,055,000	6,250	4,234,000	10,647,000	14,881,000	1,823,000
Nanviak #2	9	2.1	1.4	960,498	5,000	2,117,000	7,067,000	9,184,000	911,500
B-1	98	98	3	96,050,000	3,500	3,074,000	5,907,000	8,981,000	9,925,000
B-2	17	17	3	16,662,000	1,000	533,000	3,761,000	4,294,000	1,722,000
B-3	18	18	3	17,642,000	7,500	565,000	7,885,000	8,450,000	1,823,000
B-4	27	15	3	14,702,000	6,250	6,351,000	2,626,000	8,977,000	2,734,500
B-5	30	30	3	29,403,000	1,250	941,000	4,661,000	5,602,000	3,038,500

[1] Assumes 25% losses.
[2] Tabler and others, 1990 - includes losses.
[3] Snow - precipitation - October through May = 8.61" (water equiv.) - 25% losses = 6.46". Volume calculated as total equivalent contributing snowmelt.
[4] Rain - precipitation - June through September = 6.55" - 2.8" losses = 3.75".

ATTACHMENT 14

ESTIMATED ANNUAL FLOW CHARACTERISTICS[1]
CHEFORNAK, ALASKA

WATERSHED	AREA (Acre/Sq Mi)	ELEVATION RANGE (ft)	LOW MONTH (cfs)	ANNUAL PEAK (cfs)	MEAN ANNUAL (cfs)
East Creek	9,154/14.3	20-443	4.3	143	14.3
WS - A	525/0.8	25-75	0.2	8	0.8
WS - B	560/0.9	25-50	0.3	9	0.9
West Creek	285/0.4	20-75	0.1	4	0.4

[1] Balding, 1976.

ATTACHMENT 15

ESTIMATED MEAN MONTHLY FLOW,[1] CFS
CHEFORNAK, ALASKA

WATERSHED	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
East Creek	29.6	8.5	3.0	1.3	0.8	0.5	0.5	25.7	142	78	68.3	65.7
WS - A	1.8	0.5	0.2	0.1	0.1	0	0	1.6	8.7	4.8	4.2	4.0
WS - B	1.8	0.5	0.2	0.1	0.1	0	0	1.6	8.7	4.8	4.2	4.0
West Creek	0.9	0.3	0.1	0	0	0	0	0.8	4.4	2.4	2.1	2.0

[1] Based on gaged flows for Crater Creek near Nome, Alaska.