7. SURFACE WATER HYDROLOGY

7.1 Regional Study Area

7.1.1 Introduction

The hydrological studies were designed to gather a general understanding of the regional hydrology for the Bristol Bay drainage basin along with more detailed information about the specific drainages surrounding and/or adjacent to the Pebble Deposit.

The Bristol Bay drainage basin encompasses 41,900 square miles in southwestern Alaska (Figure 1-2b in Chapter 1). The largest rivers draining into Bristol Bay are the Nushagak and Kvichak rivers. Their drainage areas – 12,700 square miles and 8,000 square miles, respectively – comprise 49 percent, by area, of the Bristol Bay drainage basin. The following information about the regional hydrology was obtained from the sources listed:

- Data from active and discontinued gaging stations in the Bristol Bay watershed obtained from the U.S. Geological Survey (USGS) website (USGS, 2010).

- Regional peak flow information from *Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins* (Curran et al., 2003).

- Active snow-course information for the Bristol Bay drainage from the Natural Resources Conservation Service website (NRCS, 2010).

7.1.2 Results and Discussion

The USGS historically has collected regional streamflow records at 24 gaging stations in the Bristol Bay drainage. As of 2008, only eight of these gaging stations were active. The paucity of regional hydrologic data prompted the Pebble Project to undertake an intensive, long-term hydrologic gaging program in the mine study area, and to collect supplementary hydrologic information in the transportation corridor study area.

The regional peak flow values for 2-year and 200-year floods were estimated by Curran et al. (2003) for eleven gaging stations in the region. The unit-discharge values for the flood estimates generally decrease with increasing basin area, as expected, but considerable other variability is also evident. The peak flow estimates are weighted values obtained using flood frequency analysis of the individual gage records and a set of regional regression equations. The regression equations had large standard errors, meaning that peak flows were not well correlated to basin characteristics across the diverse and sparsely gaged region. Therefore, the weighting procedure of Curran et al. (2003) placed more emphasis on flood estimates based on local gage records than on the regional regression estimates.

The six Natural Resources Conservation Service regional snow courses are all located along the eastern side of the Bristol Bay drainage on the lee side of the Alaska and Aleutian ranges with respect to southeasterly atmospheric flows. Thus, these snow courses are representative of lowland and foothill areas adjacent to the mountain ranges, but are not representative of the mountainous headwater areas of the larger rivers in the region.

7.2   Mine Study Area

7.2.1   Introduction

The mine study area (Figure 1-4 in Chapter 1) straddles the boundary of the Nushagak River and Kvichak River watersheds. Within the mine study area, the general deposit location straddles the watershed boundary between the South Fork Koktuli River (SK) and Upper Talarik Creek (UT) and lies close to the headwaters of the North Fork Koktuli River (NFK; Figure 7-1). The mine study area encompasses the drainages of these three watercourses, as well as the headwaters of Kaskanak Creek (KC), which is located adjacent to the lower part of the SK basin. The NK, SK, UT, and KC watersheds encompass a combined area of 373 square miles above the lower-most gaging station in each watershed. Field studies to gather more detailed information in these drainages included the following programs:

- Streamflow Gaging Program—the USGS has operated three streamflow gaging stations in the mine study area since August 2004. Pebble Project contractors have installed and operated another 26 continuous flow gaging stations during that period. The gaging stations are distributed along the main stream and tributary channels of the four watersheds in the study area and on the lower reach of the nearby Newhalen River (Figure 7-1). (Basin characteristics and periods of record for each gaging station are provided in Table 7-1.) At each continuous flow station operated by Pebble Project contractors, stage (water level) was recorded every 15 minutes during ice-free months. During ice affected flow conditions, instantaneous flow measurements were obtained at regular intervals, typically monthly, at all Pebble Project stations.

- Winter hydrographs for USGS stations SK100B, UT100B, and NK100A were estimated by the USGS using instantaneous flow measurements in conjunction with meteorological data and a general understanding of hydrograph recession patterns during winter low-flow conditions. Winter hydrographs for the stations operated by Pebble Project contractors were estimated on the basis of instantaneous wintertime flow measurements and by correlations with USGS station hydrographs.

- Low-flow measurements were collected at 55 sites along gaged channels during low-flow events, usually in late winter. Direct instantaneous measurements of peak flows were rarely possible because high-flow events are difficult to predict, short in duration, and often unsafe or impractical to measure.

Data from the streamflow gaging program supported the following studies:

- Hydrologic Analysis—a network of continuous discharge gaging stations was installed and maintained to derive an understanding of general hydrologic conditions and the seasonal and spatial variability of surface runoff throughout the study area.

- Low Flow Analysis—periods when streamflow was comprised predominantly of groundwater upwelling or baseflow (i.e., that portion of streamflow not directly attributable to precipitation or snowmelt runoff), were identified, the baseflows were measured, and observed baseflow patterns were related to groundwater flow patterns.

- Peak Flow Analysis—USGS regional regression equations for peak flows were adjusted based on the short-term peak flow records from the study area gaging stations.

- Snow Distribution Survey—snow survey locations were chosen to represent predominant slope, aspect, and elevation zones and were distributed across the main watershed and smaller subcatchment areas to correspond with gaging station locations. Baseline snow depth and density data were collected to characterize snow distribution and ablation (loss through melt, sublimation, or wind transport) in the major drainage basins of the study area for input to baseline water-balance studies including the development and calibration of a snow distribution model. Ablation rates were estimated by regularly resurveying snow course plots and plots along selected transects following the initial mid-April snow survey. Aerial photographs and satellite imagery were also used to estimate large-scale patterns of snow accumulation and ablation in the mine study area. A snow model was developed based on terrain characteristics and climate data, and model outputs were compared to the field-survey ablation estimates.

7.2.2   Results and Discussion

7.2.2.1   Hydrologic Analysis

The topography of the study area is relatively gentle, consisting of elevations ranging from around 3,000 feet on Groundhog Mountain to 46 feet at Iliamna Lake. Glacial and fluvial sediments of varying thickness cover most of the area at elevations below about 1,400 feet and play an important role in surface water runoff and groundwater storage and exchange. In several areas, subsurface flows follow former preglacial surface drainage pathways that have since been buried by subsequent sediment deposits, resulting in one known location of substantial cross-basin (SK to UT) groundwater flow.

The annual pattern of streamflows in the mine study area is characterized by high flows in spring resulting from snowmelt, low flows in early to mid-summer resulting from dry conditions and depleting snowpacks, another high-flow period in late summer and early autumn resulting from frequent rainstorms, and the lowest flows in winter when freezing occurs and most precipitation falls as snow. Figure 7-2 shows these seasonal patterns in a representative hydrograph from USGS gaging station SK100B, on the South Fork Koktuli River, for the 2004-2005 water year.

The 2004 through 2008 period of record includes a range of hydrologic conditions. The complete study-period hydrograph for Station SK100B is presented on Figure 7-3, which illustrates the range and pattern of streamflows typical of most of the gaging stations. The

average volume of runoff in the spring and autumn seasons has been approximately equal throughout the period of record. The duration of spring snowmelt is shorter than the summer/fall rainstorm season, so average monthly flows are highest in May, followed by September and October. Annual maximum daily and instantaneous flows can occur in either season.

The mean annual discharge and unit runoff for each gaging station in the mine study area are shown in Table 7-1. At the USGS gaging stations located on the lower reaches of the SK, NK, and UT, the mean annual unit runoff is measured to be approximately 2.6 to 2.8 cubic feet per second (cfs) per square mile (mi^2). This equates to 35 to 38 inches of runoff depth. Elsewhere, mean annual unit runoff varied from gage to gage because of catchment topography and precipitation, cross-drainage transfers of groundwater, surface and subsurface flow exchanges along stream channels, and seasonal redistribution of snow by wind. In the KC watershed, which has relatively low terrain, the mean annual unit runoff at gage KC100A was 1.4 cfs/mi^2, or 19 inches of runoff depth. The upland tributary streams in the NK and SK watersheds demonstrated relatively high runoff, with mean annual unit runoff values at gages NK119A and SK119A of 3.2 cfs/mi^2 and 3.4 cfs/mi^2, respectively, or 43 to 46 inches of runoff depth.

Groundwater plays a prominent role in the flow patterns of all the creeks and rivers that were studied, but its role was especially notable at SK100C, which goes dry seasonally because of upstream losses of surface flow to groundwater, and at UT119A, which gains flow from the SK to such an extent that its hydrograph is dominated by baseflow. High annual unit runoff values were recorded at UT119A because much of the streamflow at that gaging station is not generated within the topographic watershed boundaries, but rather enters via subsurface pathways that cross the topographic divide. Conversely, low annual unit runoff values were recorded at SK100C because of upstream losses of groundwater to the UT watershed and the bypassing of additional groundwater beneath the gage prior to its upwelling into the channel further downstream. A small cross-basin transfer of groundwater may also occur from the upper NK watershed into the upper UT watershed, upstream of gaging station UT100E, but this is less certain than the SK to UT groundwater transfer and is considerably smaller in magnitude if it does occur. Similarly, given the very low divide between the lower reaches of the SK and the headwaters of KC, the possibility of cross-basin transfer of water in this area was investigated; however, a review of the relevant flow data did not show evidence that this phenomenon was occurring.

7.2.2.2   Low Flow Analysis

Low-flow periods occur between rainstorms in the summer and during the winter freeze period, both times when surface flows in streams are supplied entirely by groundwater discharge. During the 2004 through 2008 period of record, baseflows were higher during the summer than during the winter because of recent snowmelt recharge of aquifers and intermittent rainstorms. Baseflows were lowest in late winter, after several months without surface runoff. Average late-winter baseflow values for each gaging station are provided in Table 7-1. Spatial and temporal patterns in baseflow conditions are useful for estimating groundwater discharge rates and for inferring groundwater gains and losses along channels and between basins. Low-flow conditions are also influenced by fluctuations in surface-storage features such as lakes, ponds, and wetlands; however, changes in surface storage are minimized during the late winter freeze.

In addition to flow measurements, wintertime surveys of open water were used to determine areas of groundwater upwelling. Groundwater is several degrees warmer than surface water in the winter, and correspondingly strong upwelling areas generally do not freeze over and are visible from the air.

Gaining and losing reaches along rivers occur within all the study-area basins, though they are most pronounced in the mainstem of the SK. Each major river valley is partially filled with glacial drift and outwash with varying permeability. Conversely, each channel also regains flow where the bedrock valley narrows downstream, forcing groundwater up from the subsurface. General patterns of upwelling and percolation along all three main channels are shown on Figure 7-4, which presents the distribution of open water and dry channels in late winter of 2006. The channel sections with no flow are those in which surface flow has been lost to the subsurface (through percolation). The channel sections with open water are those in which upwelling flows have prevented the formation of ice.

7.2.2.3   *Peak Flow Analysis*

Peak discharges recorded at continuous discharge gaging stations occurred either as a result of spring snowmelt or autumn rainstorms. Peak flow unit runoff displayed a similar pattern to mean annual unit runoff. The maximum recorded peak flow unit runoff varied from greater than 50 cfs/mi^2 in the upland tributaries to 15 to 25 cfs/mi^2 at gages on the lower mainstem channels. The lowest peak flow unit runoffs were recorded at gages with large groundwater influences, resulting from either loss of flow or buffering of peak flows due to groundwater storage. Beaver dams also may attenuate peak flows in some smaller basins.

USGS regional regression equations were used to estimate peak flows for return periods from 2 years to 500 years at each of the continuous discharge gaging stations with three or more years of record. According to the USGS equations, the recorded mean annual peak flows for gaging stations on main stream channels have predicted return periods of 5 to 20 years. The maximum recorded peak flows at these gages, based on record lengths of 4 years (or less), have predicted return periods of 10 to 200 years. The recorded mean annual peak flows for gaging stations on steep upland tributaries have predicted return periods greater than 50 years. The maximum recorded peak flows at these gages, based on record lengths of 4 years (or less), have predicted return periods greater than 100 years

These results indicate that the regional regression equations likely underestimate peak flows in the mine study area in general and in upland tributaries within the mine study area in particular. Thus, an alternative approach to peak flow estimation was warranted. A combined local/regional approach was developed to improve the peak flow estimates. The local gage records were used to estimate the 2-year peak flow magnitudes at each gaging station. The magnitudes of larger peak flows were scaled from the 2-year peak flows according to the ratios specified by the USGS regression equations. The estimated 200-year peak flow magnitude at each gaging station is provided in Table 7-1.

7.2.2.4   Snow Surveys and Modeling

Snow accumulation and snowmelt drive streamflow patterns throughout winter and spring. As snow accumulates and surface water freezes, streamflows drop to baseflow levels. Baseflows typically drop gradually until April as groundwater levels decrease in the absence of surface input. The spring snowmelt event typically extends from mid- to late April through June.

Snow does not accumulate evenly across the study area, and it is redistributed frequently during high-wind events. Annual surveys indicated that mid-April snow depth varied from 0 at wind-scoured sites to more than 207.7 inches in deep drifts on the leeward side of ridges. The mean mid-April snow/water equivalent measured at the two study-area snow courses was 10.3 inches at Snow Course 1 and 10.4 inches at Snow Course 2.

Ablation was measured between mid-April and mid-June along the two snow courses. Regional ablation was estimated using satellite imagery taken repeatedly during the snowmelt period each year and a model that related snow-covered area as seen on the satellite images to the snow/water equivalent.

A snow distribution model was used to estimate the mean snow/water equivalent for each gaging-station drainage basin for 2006 to 2008, based on topography, wind speed and direction, and extrapolated field measurements. The modeling results are presented in Table 7-2, and the modeled spatial distribution of the snow/water equivalent in April 2007 is shown on Figure 7-5. In any given year, the basins with the highest modeled snow/water equivalent values were those located in the upper portions of the SK, NK, or UT watersheds. The basins represented by the gaging stations on the lower reaches of the SK, NK, and UT had lower snow/water equivalent values because of the inclusion of lower-elevation terrain in those basins. Station KC100A, which has the lowest-elevation basin, also had the lowest modeled snow/water equivalent each year.

An ablation model was used to estimate melt rates for each drainage basin each year, based on field survey data, satellite imagery, and meteorological data. In general, the timing of snowmelt predicted by the ablation model matches the stream hydrographs reasonably well.

7.3   Transportation-corridor Study Area

7.3.1   Introduction

The transportation-corridor study area extends along the north shore of Iliamna Lake from the Newhalen River in the west to the boundary between Bristol Bay and Cook Inlet drainages in the east (Figure 7-6). All of the streams that cross the transportation-corridor study area flow directly or indirectly into Iliamna Lake.

The objectives of the surface hydrology studies in the transportation-corridor study area were as follows:

- Characterize annual streamflows in the anadromous fish-bearing stream channels that cross the transportation-corridor study area.

- For these channels, estimate maximum and minimum flow statistics and other index flows required for aquatic habitat studies.

Hydrologic conditions are influenced by local climatic and topographic conditions. These conditions vary significantly along the transportation-corridor study area, with mountainous terrain and maritime coastal climate conditions in the east and lower-relief terrain with transitional maritime/continental climate conditions in the west.

Basin and channel characteristics and spot discharge measurements were compiled in 2004 and 2005 at 15 sites on 14 streams in the study area, including two USGS gaging stations – Roadhouse Creek (USGS Station 15300200) and Iliamna River (USGS Station 15300300) – which are collocated with Pebble Project stations (Figure 7-6). Crest gages were installed to record instantaneous stage peaks, but stage discharge rating curves were not developed and peak discharge estimates associated with the stage peaks are not presented. Basin characteristics and the periods of record during which spot discharge measurements were collected at each gaging station are provided in Table 7-3.

The USGS provides regional regression equations for estimating low-duration, high-duration, and peak flow statistics based on basin characteristics (Wiley and Curran, 2003; Curran et al., 2003). These equations were used to estimate flow statistics at each of the 15 stream gaging sites. Low-duration flows are flows that are exceeded much of the time; the USGS equations provide results for flows that are predicted to be exceeded 50 percent to 98 percent of the time. High-duration flows are flows that are exceeded relatively infrequently; the USGS equations provide results for flows that are predicted to be exceeded 1 percent to 15 percent of the time. Peak flows are extreme high flows that are predicted to be exceeded only once, on average, within specified return periods expressed in years.

7.3.2   Results and Discussion

The annual pattern of streamflows in the study area is represented by the two USGS gaging stations. Roadhouse Creek (USGS Station 15300200), located in the western part of the study area, has a mean annual basin runoff depth of 19 inches. The Iliamna River (USGS Station 15300300), located in the eastern part of the study area, has a mean annual basin runoff depth of 96 inches. The annual hydrograph at the USGS gaging station on Roadhouse Creek is dominated by spring snowmelt and autumn rainfall, with low flows in the summer and winter. The autumn rains produce greater runoff volume than spring snowmelt, on average, and the winter flows are lower than the summer flows. The annual hydrograph at the USGS gaging station on the Iliamna River is somewhat similar to the Roadhouse Creek hydrograph except that in the Iliamna River spring flows are greater than autumn flows (because of snow accumulation and melt in the higher mountainous basin) and the summer low-flow season is not as pronounced as in Roadhouse Creek (because of prolonged snow and glacier melt throughout the summer).

The low-duration flows that are predicted to be exceeded 98 percent of the time in the month of August are presented in Table 7-3. These results were computed for each gaging station

according to the USGS regression equations in Wiley and Curran (2003). Most of the measured flows in August 2004 corresponded to flows that had exceedence durations of greater than 90 percent, consistent with the general observation that August 2004 was relatively dry so the streamflows during August 2004 were expected to be well below average and should be exceeded most of the time.

The estimated 200-year peak streamflow values for each gaging station, based on the USGS regression equations (Curran et al, 2003), are presented in Table 7-3. These peak flow estimates are based on the state precipitation map produced by Jones and Fahl (1994), which appears to underestimate mean annual precipitation in the eastern part of the study area (based on measured basin runoff in the Iliamna River).

The peak flow estimates based on the regional regression equations were compared to the gage records from Roadhouse Creek and the Iliamna River. The regional peak flow estimates appear to over-predict peak flows in the western part of the study area and under-predict peak flows in the eastern part of the study area, even when appropriate values of mean annual precipitation are used in the regression equations.

7.4   References

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TABLE 7-1
Streamflow Gaging Stations, Mine Study Area

Watershed	Station	Principal Operator	Period of Record	No. Complete Water Years	Basin Area (mi²)	Mean Basin Elev. (ft.)	Mean Annual Discharge [a] (cfs)	Mean Annual Unit Runoff [a] (cfs/mi²)	Estimated Baseflow [b] (cfs/mi²)	200-Year Peak Flow [c] (cfs/mi²)
South Fork Koktuli River	SK100A	HDR	2004-07	3	106.92	1,115	269.3	2.52	0.7	42
	SK100B	USGS	2004-08	4	69.33	1,255	191.0	2.76	0.7	57
	SK100B1	HDR	2006-07	2	54.41	1,290	113.0	2.08	0.3	-
	SK100C	HDR	2004-08	4	37.50	1,230	52.2	1.39	0.0	40
	SK100F	HDR	2004-07	3	11.91	1,270	28.1	2.36	0.5	61
	SK100G	HDR	2004-07	3	5.49	1,200	14.7	2.68	0.4	82
	SK119A	HDR	2004-08	4	10.73	1,575	36.9	3.44	0.7	293
	SK124A	HDR	2005-08	4	8.52	1,460	19.8	2.32	-	203
North Fork Koktuli River	NK100A	USGS	2004-08	4	105.86	1,280	270.3	2.55	1.0	60
	NK100A1	HDR	2007-08	2	85.34	1,340	203.8	2.39	0.6	-
	NK100B	HDR	2007-08	2	37.32	1,420	86.0	2.31	0.5	-
	NK100C	HDR	2004-08	4	24.35	1,360	52.4	2.15	0.6	48
	NK119A	HDR	2004-08	4	7.76	1,645	24.6	3.17	0.4	209
	NK119B	HDR	2007-08	2	3.97	1,430	4.8	1.21	0.0	-
Upper Talarik Creek	UT100-APC3	APC	2007-08	1	134.16	1,013	382.3	2.85	-	-
	UT100-APC2	APC	2007-08	1	110.16	965	316.9	2.88	-	-
	UT100-APC1	APC	2007-08	1	101.51	881	291.8	2.87	-	-
	UT100B	USGS	2004-08	4	86.24	1,055	231.7	2.69	1.3	43
	UT100C	HDR	2007-08	2	69.47	1,130	162.4	2.34	0.9	-
	UT100C1	HDR	2007-08	2	60.37	1,170	123.3	2.04	0.6	-
	UT100C2	HDR	2007-08	2	48.26	1,210	107.2	2.22	0.5	-
	UT100D	HDR	2004-08	4	11.96	1,110	29.5	2.47	0.7	69
	UT100E	HDR	2004-08	4	3.10	1,225	10.1	3.27	1.3	77
	UT106-APC1	APC	2008	0	14.14	713	-	-	-	-
	UT119A	HDR	2004-08	4	4.05	882	27.4	6.77	5.5	36
	UT135A	HDR	2007-08	2	20.42	1,170	41.2	2.02	0.5	-
Kaskanak Creek	KC100A	HDR	2004-08	4	25.64	605	36.1	1.41	-	37
Newhalen River	NH100-APC2	APC	2008	0	3451	-	-	-	-	-
	NH100-APC3	APC	2008	0	3412	-	-	-	-	-

Notes:

a. Mean annual discharge and unit runoff for the period of record, based on complete water years.

b. Average discharge recorded during late-winter baseflow-measurement events.

c. 200-year instantaneous peak flows were estimated using a combined local/regional approach for stations with at least three years of record.

cfs = cubic feet per second

ft = feet

mi² = square miles

TABLE 7-2
Snow Model Results, Mine Study Area

Watershed	Station	Basin Area (mi^2)	Mean Basin Elev. (ft.)	Modeled Mean Snow/Water Equivalent for Basin (inches)		
				04/19/06	04/09/07	04/06/08
South Fork Koktuli River	SK100A	106.92	1,115	19.5	4.5	19.3
	SK100B	69.33	1,255	21.3	5.7	21.7
	SK100B1	54.41	1,290	21.5	5.8	22.0
	SK100C	37.50	1,230	21.2	5.5	22.2
	SK100F	11.91	1,270	21.8	6.3	23.7
	SK100G	5.49	1,200	21.4	5.9	23.9
	SK119A	10.73	1,575	23.3	6.9	22.6
	SK124A	8.52	1,460	22.3	6.5	22.7
North Fork Koktuli River	NK100A	105.86	1,280	21.5	6.1	23.8
	NK100A1	85.34	1,340	22.3	6.6	25.1
	NK100B	37.32	1,420	22.8	6.6	25.8
	NK100C	24.35	1,360	22.6	6.3	26.3
	NK119A	7.76	1,645	23.8	7.5	24.8
	NK119B	3.97	1,430	22.3	6.4	25.1
Upper Talarik Creek	UT100-APC3	134.16	1,013	17.6	3.4	16.4
	UT100-APC2	110.16	965	18.4	3.9	18.0
	UT100-APC1	101.51	881	18.9	4.2	18.9
	UT100B	86.24	1,055	19.2	4.4	19.6
	UT100C	69.47	1,130	19.9	5.0	20.9
	UT100C1	60.37	1,170	20.3	5.3	21.3
	UT100C2	48.26	1,210	20.6	5.6	21.9
	UT100D	11.96	1,110	20.5	5.8	22.6
	UT100E	3.10	1,225	21.4	6.3	25.1
	UT106-APC1	14.14	713	-	-	-
	UT119A	4.05	882	18.1	2.0	17.2
	UT135A	20.42	1,170	19.9	4.8	21.5
Kaskanak Creek	KC100A	25.64	605	13.0	0.2	9.3
Newhalen River	NH100-APC2	3451	-	-	-	-
	NH100-APC3	3412	-	-	-	-

ft = feet
mi^2 = square miles

TABLE 7-3
Gaging Station Basin Characteristics, Transportation-corridor Study Area

Station [a]	Stream	Period of Record	Drainage Basin Characteristics			
			Area (mi^2)	Mean Elev. (ft)	Flow Exceeded 98% of the Time in August (cfs) [c]	200-year Peak Flow (cfs) [d]
GS-23	Chinkelyes Creek	2004-05	22.55	1,616	43	2,388
GS-3a	Iliamna River	2004-05	128.00	2,236	304	9,609
GS-4a	Pile River	2004-05	152.83	1,463	300	11,532
GS-4b	Unnamed Outlet Creek from Long Lake	2004-05	-	-	-	-
GS-6a	Unnamed Outlet Creek from Dumbbell Lake	2004-05	2.20	1,072	2	191
GS-7a	Unnamed Outlet Creek near Pedro Bay Townsite	2004-05	3.36	1,176	2	330
GS-8a	Knutson Creek	2004-05	35.70	2,300	45	2,271
GS-11a	Canyon Creek	2004-05	36.20	2,257	35	1,661
GS-12a	Chekok Creek	2004-05	50.48	1,764	45	2,097
GS-14a	Unnamed Creek East of Eagle Bay Creek	2004-05	18.34	860	9	865
GS-14b	Unnamed Creek West of Chekok Creek	2004-05	15.91	973	9	654
GS-17a	West Fork Eagle Bay Creek	2004-05	10.95	1,190	6	585
GS-18a	Unnamed Creek on South Slope of Roadhouse Mountain	2004-05	9.29	978	4	396
GS-20 [b]	Roadhouse Creek	2004-05	20.80	321	7	689
GS-20a	Upper Roadhouse Creek	2004-05	8.07	-	-	358

Notes:

a. The gaging stations are listed in order from east to west.

b. The drainage basin characteristics for GS-20 have been adopted from the USGS gage on Roadhouse Creek (Curran et al., 2003).

c. August low-duration flow statistics estimated according to Wiley and Curran (2003).

d. Peak flow statistics estimated according to Curran et al., 2003).

cfs = cubic feet per second.

ft = feet.

mi^2 = square miles.

Typical surface hydrology gage installation (SK119A).

Surface hydrology station UT100C looking upstream, August 2008.

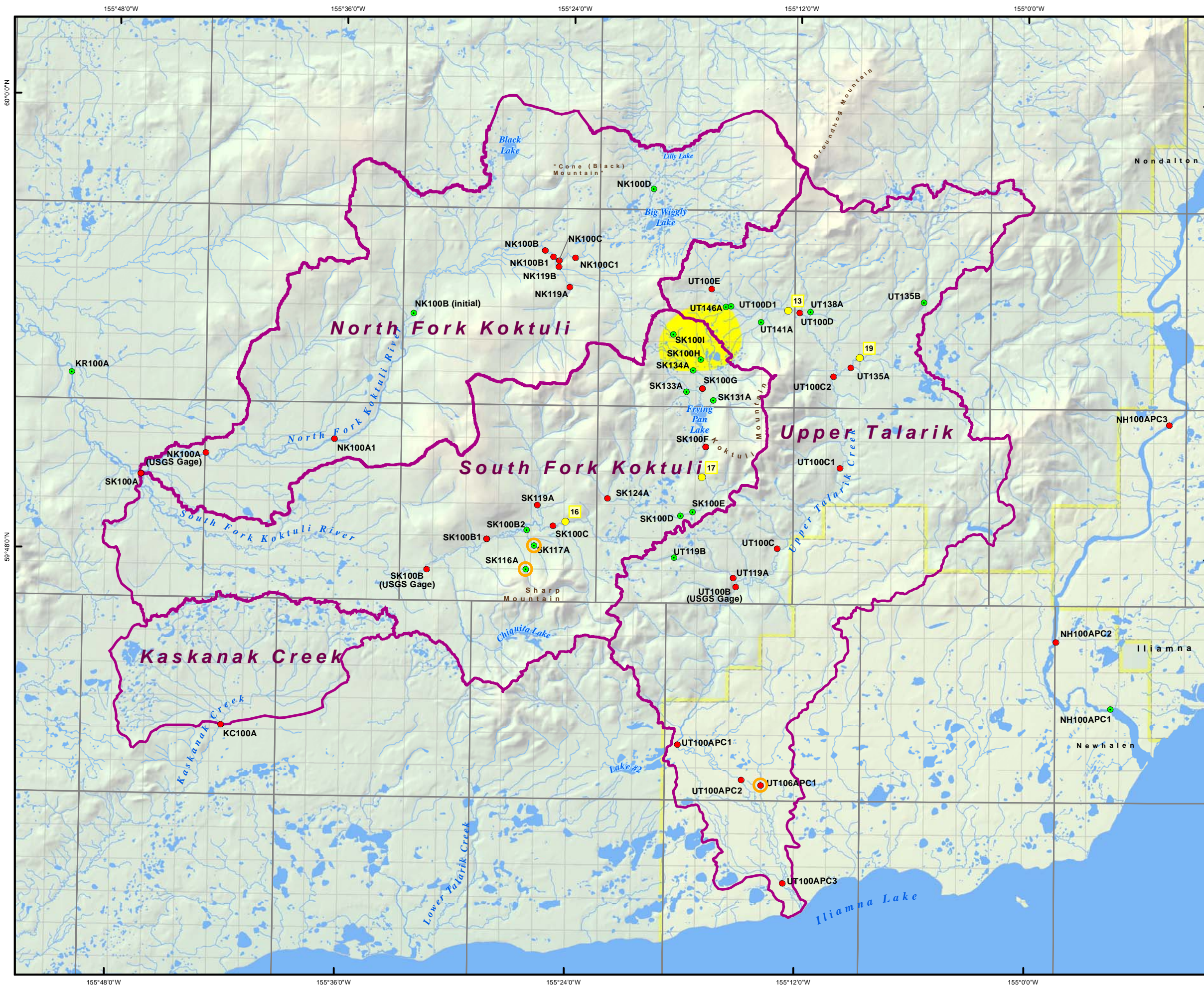

Surface hydrology station SK100C looking downstream, July 2005.

Surface hydrology station SK100C looking downstream, August 2005.

Figure 7-1
Surface Hydrology Stations
Mine Study Area

Baseline Hydrologic Stations

- Continuous
- Instantaneous
- Cominco Stations
- New 2008 Stations

Major Drainage Boundary
Stream
Water Feature
General Deposit Location
Village Corporation Boundary

SK100B2: Example of Hydrologic Station
Identification Number

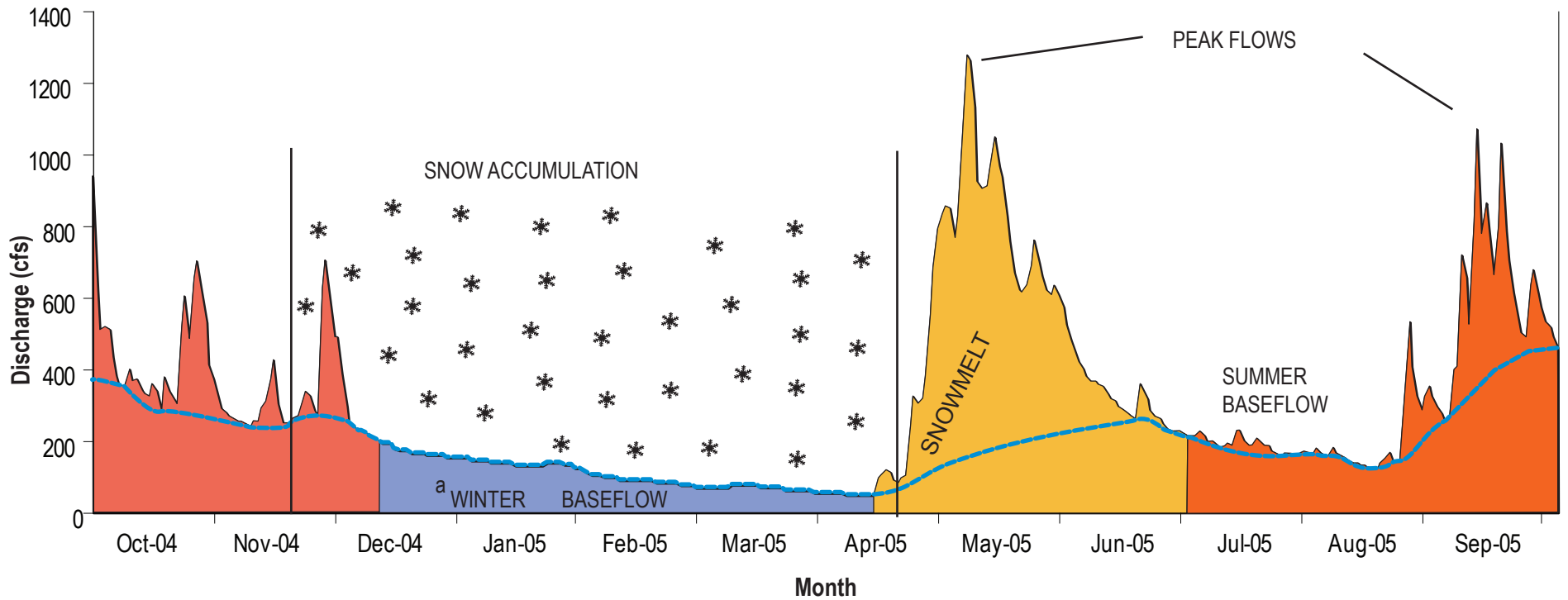Scale 1:185,000
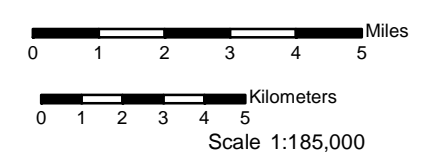
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

FIGURE 7-2
Annual Hydrograph of the South Fork Koktuli River at SK100B
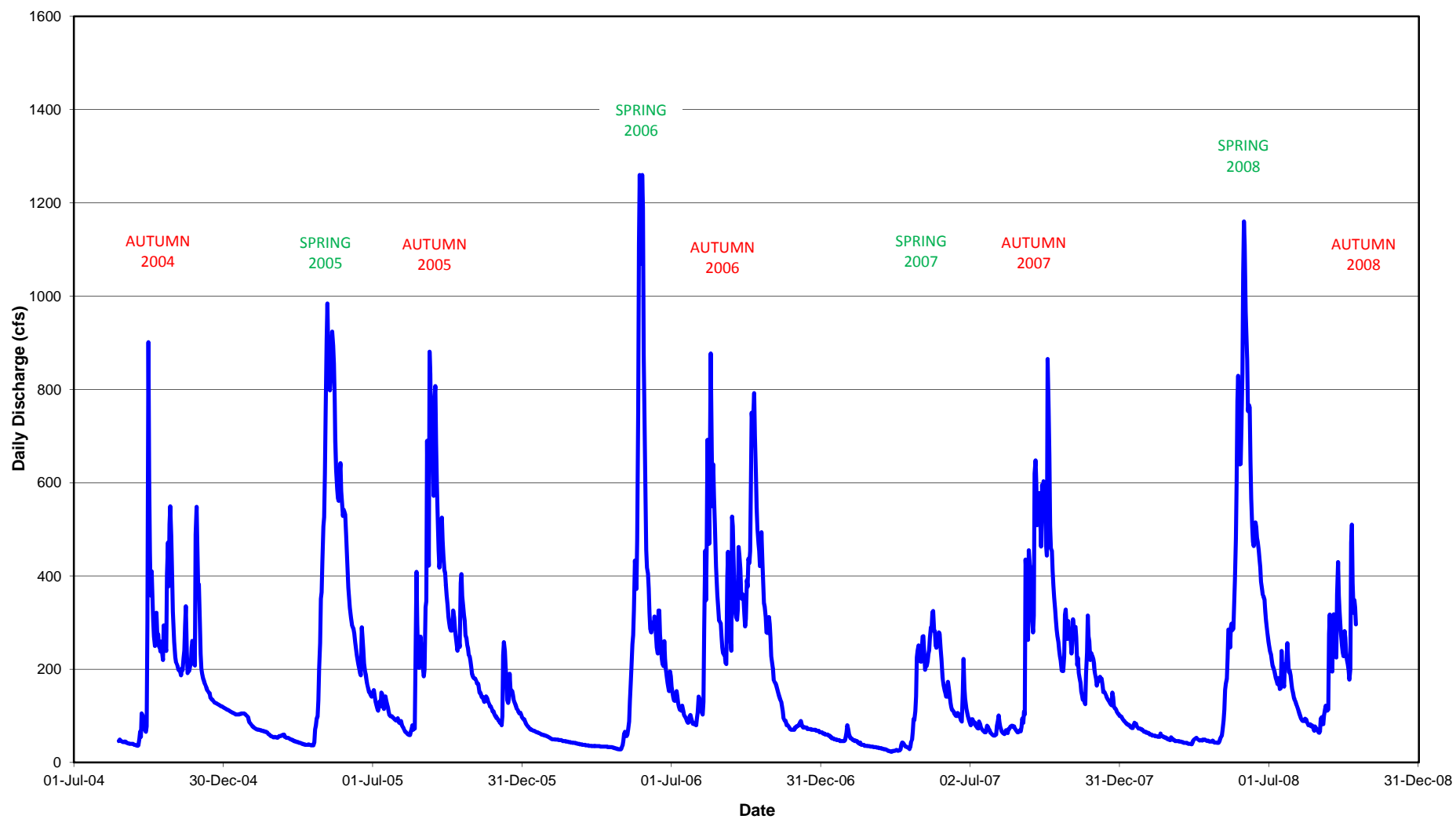
FIGURE 7-3
SK100B Hydrograph, 2004-2008

Figure 7-4
Surface Hydrology
2006 Open Water Survey Results
Mine Study Area

Open Water Survey

— Dry
— Intermittent
— Open Water

⬡ Major Drainage Boundary
～ Stream
⬬ Water Feature
● General Deposit Location
⬡ Village Corporation Boundary

SK100B2: Example of Hydrologic Station Identification Number

Scale 1:185,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

THE pebble PARTNERSHIP
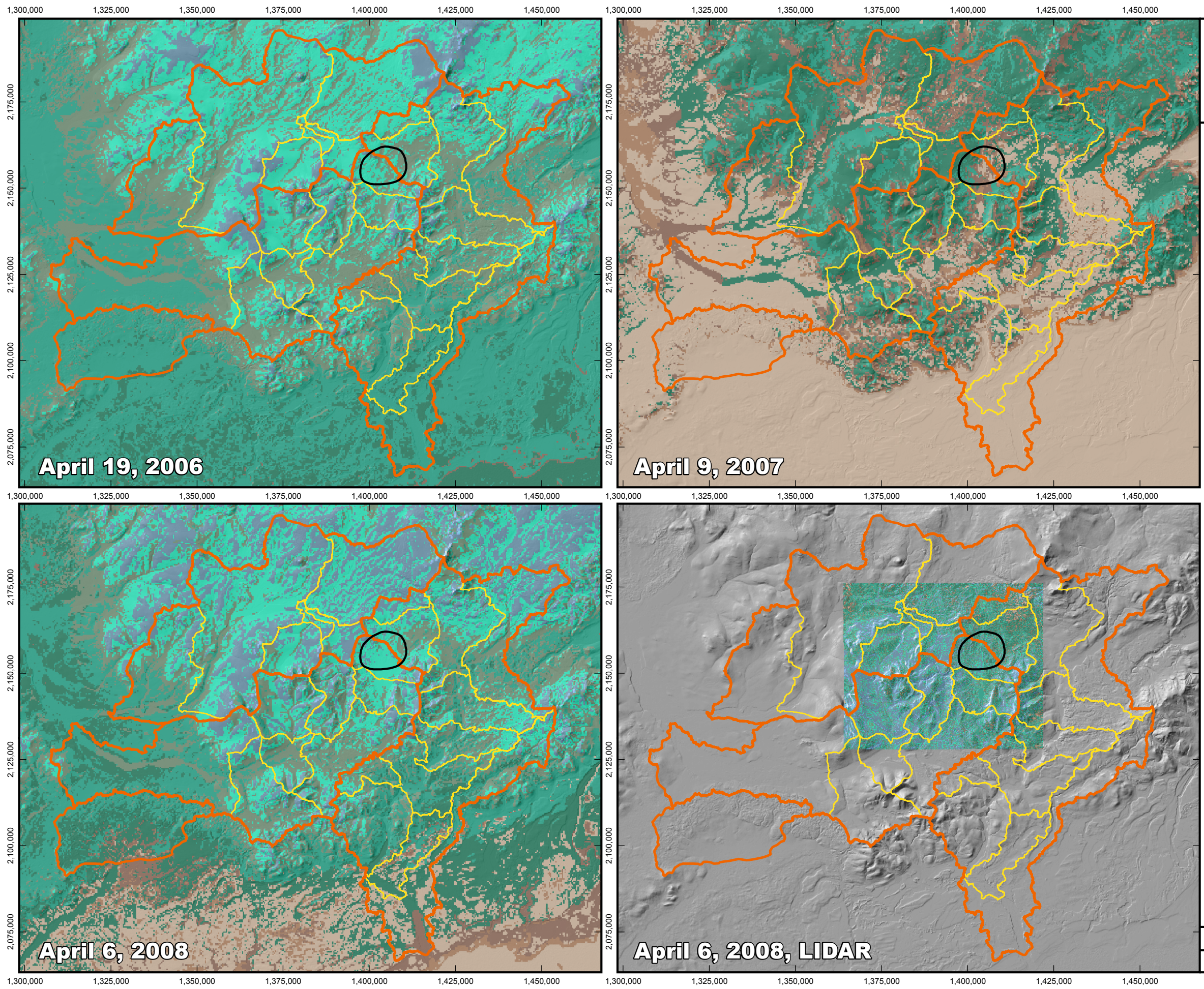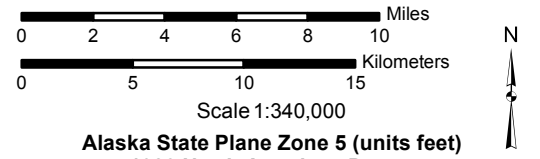
Figure 7-5
Surface Hydrology
Snow Model Output,
April, 2006–2008, Mine Study Area

Legend

Snow Water Equivalent (Inches)

	0 – 1.00
	1.01 – 3.00
	3.01 – 5.00
	5.01 – 10.00
	10.01 – 15.00
	15.01 – 20.00
	20.01 – 25.00
	25.01 – 50.00
	50.01 – 75.00
	75.01 – 100.00
	100.01 – 125.00
	125.01 – 523.00

Basin Boundary
Monitored Sub-basin Boundary
General Deposit Location

April 19, 2006

April 9, 2007

April 6, 2008

April 6, 2008, LIDAR

Scale 1:340,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 7-5_SnowDistModels_06-08_PLP_EBD_Tech_Summ_v01.mxd | Date: November 16, 2011
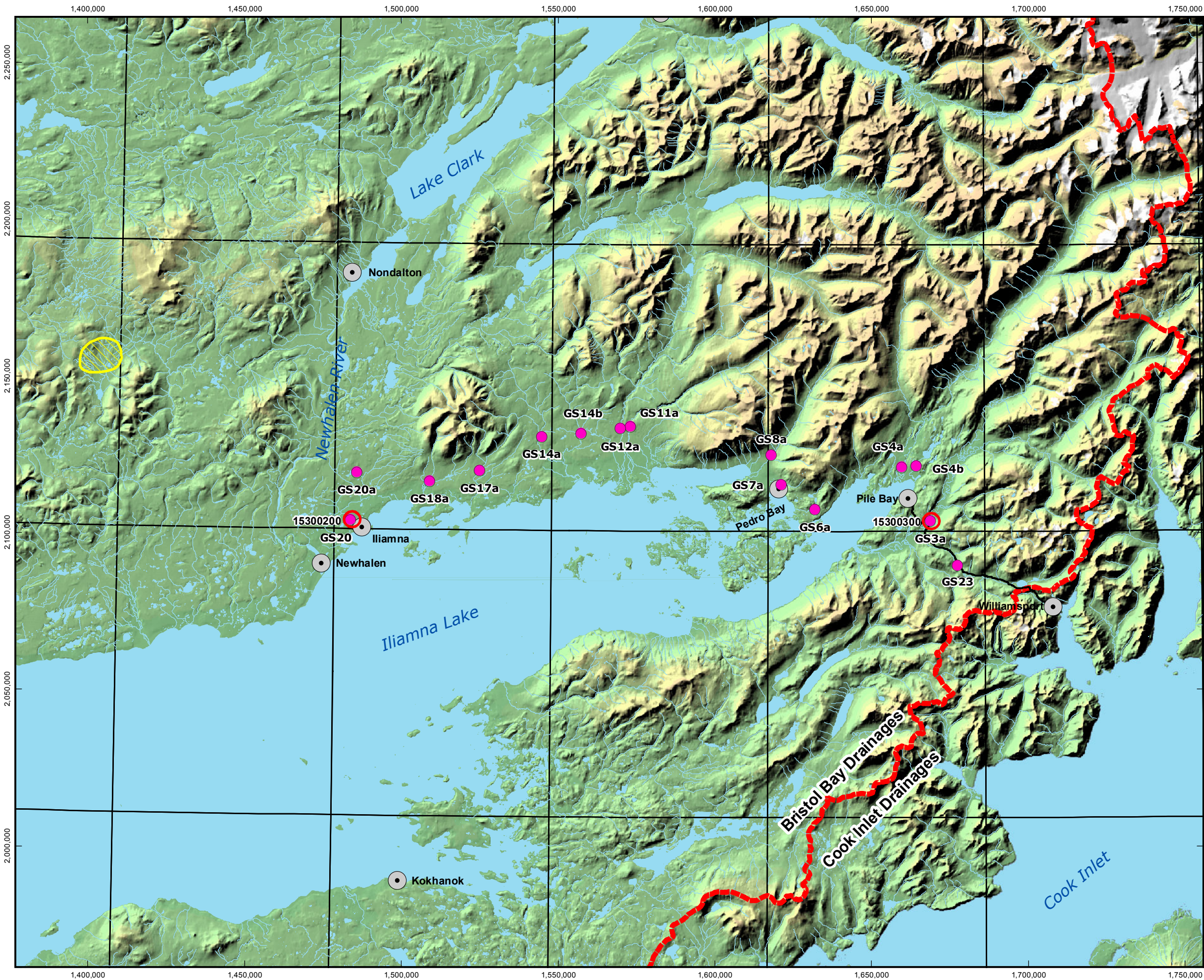Version: 1 | Author: ABR-AZC

Figure 7-6
Surface Water Gage Stations
Transportation Corridor
Bristol Bay Study Area
2004-2005

Legend

○ Surface Water Gage Station (USGS)

● Surface Water Gage Station (Pebble Project)

GS18a: Example of Pebble Project Surface Water Gage Station Identification Number.

15300300: Example of USGS Surface Water Gage Station Identification Number.

⊙ Communities

— Existing Roads

▨ General Deposit Location

▦ Bristol Bay/Cook Inlet Drainage Boundary

Scale 1:363,852
Alaska State Plane Zone 5 (units feet)
1983 North American Datum
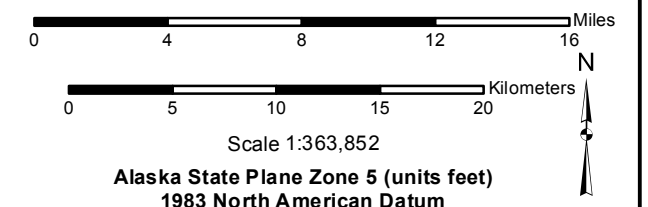
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