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Alaska Army National Guard

Baseline Water-Quality Characteristics of the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

Scientific Investigations Report 2005-5221

U.S. Department of the Interior
U.S. Geological Survey

Cover Photograph. Upstream view of the lower Stewart River, September 1, 2004. The U.S. Geological Survey (USGS) gaging station Stewart River 0.2 mile Below Durrant Creek near Nome, Alaska (USGS station number 15625900) can be seen in the lower right hand corner of the picture. Photograph taken by Josh D. Eash, U.S. Geological Survey.

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U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia: 2005

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
ounce, fluid (fl. oz)	29.57	millliters (L)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton per day (ton/d)	0.9072	metric ton per day

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Datum: North American Datum of 1927 (NAD 27 Alaska).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Baseline Water-Quality Characteristics of the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

By Josh D. Eash

Abstract

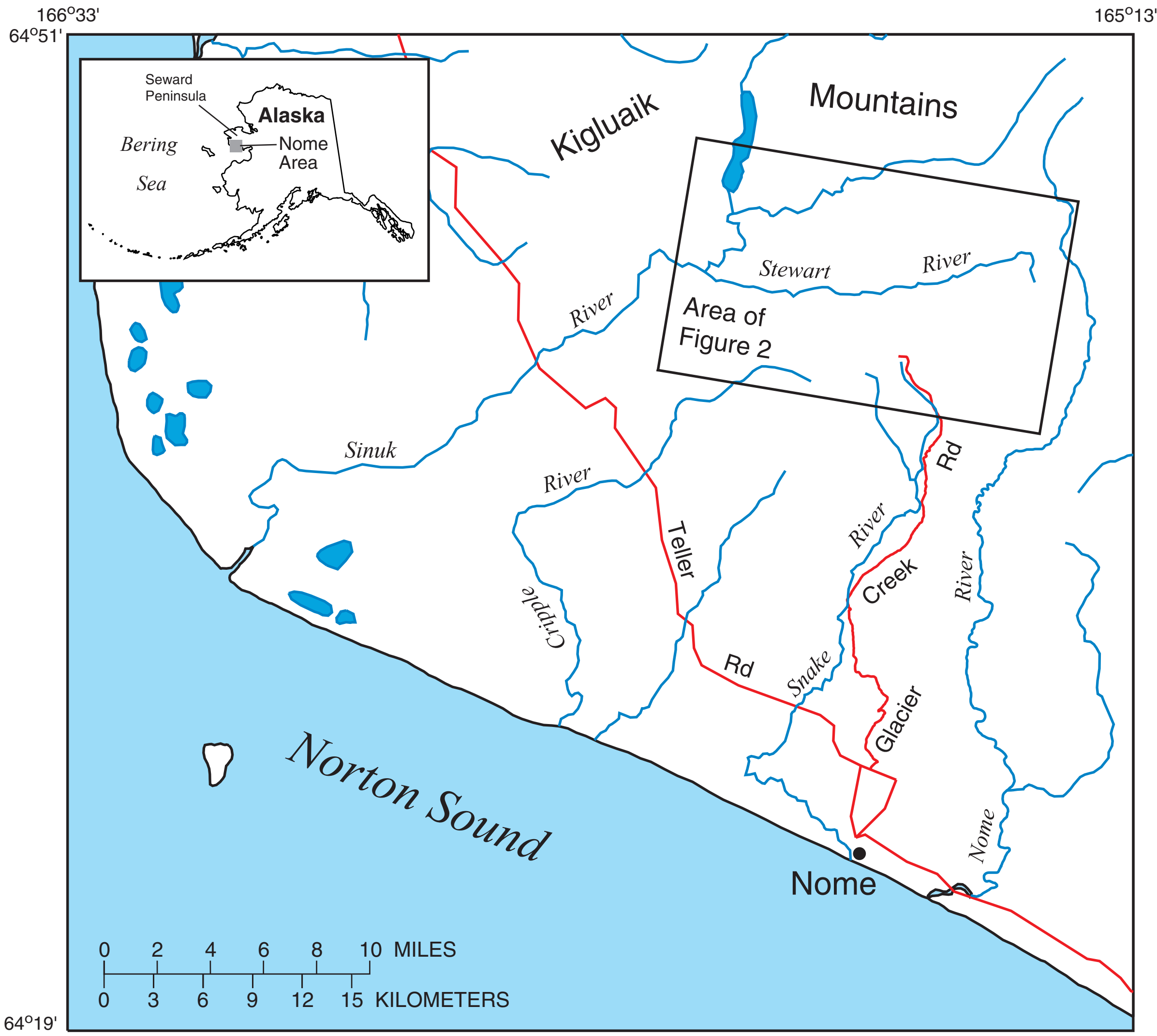
The Alaska Army National Guard Stewart River Training Area is approximately 23 miles north of Nome on the Seward Peninsula in northwest Alaska. The Stewart River Training Area encompasses much of the Stewart River Basin and a small part of the Snake River Basin. Hydrologic, water-quality, and physical-habitat data were collected at seven surface-water sites within the Stewart River Training Area during the summer runoff months (late-May to early-September) in 2004. Two of the sampling sites selected for this study were on the main stem Stewart River, one at the upstream boundary and one at the downstream boundary of the training area. Continuous hydrologic, precipitation, and water temperature data were collected at these two sites throughout the summer of 2004. Three pond sites, along the upper, middle, and lower reaches of the Stewart River within the training area, were each sampled twice during the summer of 2004 for analysis of water-quality constituents. Two tributaries to the Snake River Basin, Goldbottom Creek and North Fork Snake River, within the Stewart River Training Area boundary, also were sampled twice during the summer of 2004.

Water-quality data collected from the Stewart River at the upstream and downstream study sites indicate similar constituent concentrations. Concentrations of most water-quality constituents collected during the summer of 2004 did not exceed standards for drinking water or recreational contact. Analysis of trace-element concentrations in bed sediment samples indicate the threshold effect concentration (below which no adverse effects on organisms is expected) was exceeded for arsenic, chromium, and nickel concentrations at all sample sites within the Stewart River Training Area and cadmium, copper, zinc, and lead concentrations were found to exceed the threshold effect concentration in varying degrees at the sample sites. The probable effect concentration (above which toxic effects on organisms is likely) was exceeded by arsenic concentrations at all sites except the lower pond site. Chromium and nickel concentrations exceeded the probable effect concentration at the upstream Stewart River site and at the North Fork Snake River site.

Introduction

Background

In April 1998, a lease agreement was reached between the Alaska Army National Guard (AK ARNG) and the State of Alaska for use of approximately 24,160 acres of State land for military training exercises. The training area lies approximately 23 miles north of Nome on the Seward Peninsula in northwestern Alaska (fig. 1). Because most of the training area is within the Stewart River Basin, it has been entitled the Stewart River Training Area (SRTA) (fig. 2). One corner of the SRTA encompasses a small part of the Snake River Basin. The Stewart River drains a part of the Kigluaik Mountain foothills (known locally as the Sawtooth Mountains; National Park Service, 1987) and is a tributary of the Sinuk River, which flows to Norton Sound on the Bering Sea (fig. 1). The Stewart River Basin provides important habitats for a large variety of bird and animal species and several types of anadromous fish populations (Alaska Army National Guard, 2001).

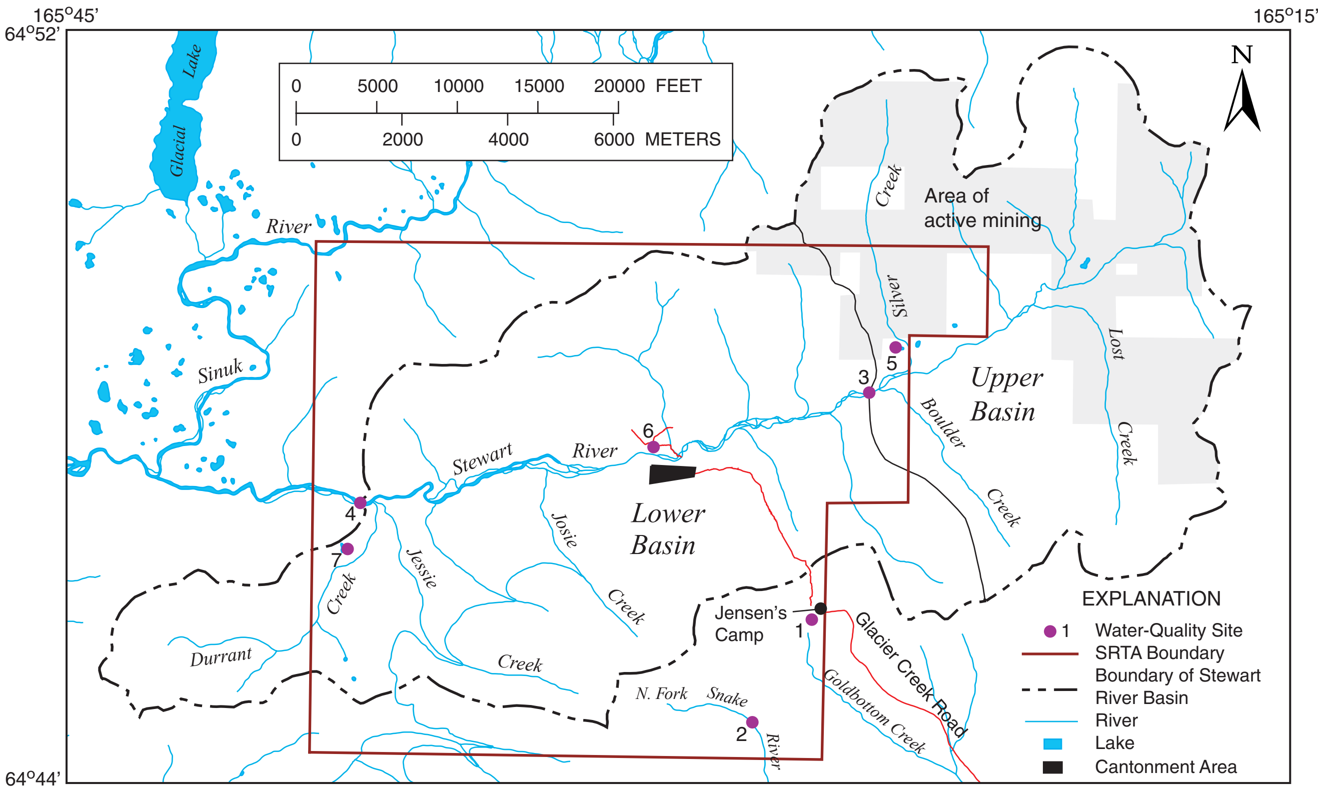


Base map modified from U.S. Geological Survey Digital Line Graphs published at 1:2,000,000
Publication projection is Albers Equal Area. Standard Parallels are 55° and 65°
Central Meridian -154° west, latitude of projection origin 50°

Figure 1. Location of Stewart River study area north of Nome, Alaska.

Guard activities on the SRTA include access to the area by Small Unit Support Vehicles (SUSV), storage of equipment and occasional bivouacking at the Cantonment Area (fig. 2), live firing exercises on the north side of Stewart River, and dismounted maneuver exercises on the south side of Stewart River. Transportation to the SRTA by the Guard, as well as the general public, is limited to SUSVs or ATVs by use of the Glacier Creek Road (also known as the Snake River Road), by snowmobile or dogsled during winter months, or by helicopter. Firing ranges are limited to the use of non-dud producing small-arms ammunition and some pyrotechnics (Alaska Army National Guard, 2001). Between 1997 and 2004, 95 percent of all training activities on the SRTA occurred during the months of July and August (Emerson Krueger, Alaska Army National Guard, written commun., 2005).

Active operations in the SRTA by the AK ARNG typically accounts for less than one month per year (Alaska Army National Guard, 2001). SUSV travel is restricted to the access trail in the SRTA, which limits the potential for stream bank erosion or elevated sedimentation in the river from that activity. The firing ranges are to the north of Stewart River and are used for small-arms training only, averaging approximately 30,000 rounds per year when training occurs (Emerson Krueger, written commun., 2005). In addition, the AK ARNG has been testing the use of a non-toxic alternative to standard lead-core bullets at firing ranges on the SRTA (Alaska Army National Guard,



Base map modified from U.S. Geological Survey Digital Line Graphs published at 1:63,360
Publication projection is Univeral Transverse Mercator, Zone 3, north. Datum is North American Datum of 1927
Central Meridian -165° west, Central Parallel 0°, scale factor 0.9996, False Easting 500,000, False Northing, 0

Figure 2. Stewart River study area showing Alaska Army National Guard Stewart River Training Area (SRTA), and U.S. Geological Survey water-quality sites.

2001). The lead-antimony core in standard bullets is replaced in Green Bullets with a non-toxic alloy consisting of tungsten-tin or tungsten-nylon. The SRTA was one of the initial test sites to prove the effectiveness of Green Bullets in August, 1998 (Pizza, 2000).

Gold has been mined in the Nome area since the end of the 19th century. Although most of the mining took place closer to Nome, there are mining claims throughout the Kigluaik Mountain foothills. In 2004, there were 24 active mining claim sites within the SRTA (Emerson Krueger, written commun., 2005) (fig. 2), and claim development is still pursued by surrounding land owners (Alaska Army National Guard, 2001). Lands in and around the SRTA also are used for subsistence and recreational hunting and fishing, as well as reindeer herding. General use of the land within the Stewart River Basin has expanded with the increased availability of all-terrain vehicles (ATVs) and snow mobiles.

The potential effects of these activities, coupled with proposed training exercises, prompted the AK ARNG to assess the quality of surface water within the SRTA. During the summer of 2004, the U.S. Geological Survey (USGS), in cooperation with the AK ARNG, conducted a study to establish a baseline data set for open-water conditions of surface-water resources within the SRTA. Data were collected to document streamflow, water-quality, bed-sediment, and physical-habitat characteristics at seven sites within the SRTA. Sampling sites included two locations on the Stewart River, three ponds along the Stewart River (upstream, middle, and downstream ponds), a site on Goldbottom Creek, and a site on the North Fork Snake River. These data will serve as a reference for proposed usage and future studies within the training area.

The AK ARNG's current lease agreement with the State of Alaska is effective until the year 2023. During this period, some environmental impacts are expected to occur and are provided for within the lease agreement. Certain impacts have been deemed "acceptable if they do not pose a significant change to ecology, environment, and/or other uses of this area." (Alaska Army National Guard, 1998). Because of these and other stipulations in the lease agreement, the AK ARNG has established specific programs to monitor and minimize the potential impacts of Guard use in the area. This cooperative study with the USGS is one part of the AK ARNG's on-going environmental monitoring and assessment process of the SRTA.

Previous Studies

Previous studies of military installations, including artillery ranges, show possible links between munitions and elevated levels of specific trace elements (Risch, 2004). Concerns identified in other studies also have included erosion, high concentrations of bacteria, and elevated turbidity levels. High concentrations of lead in bed sediments and aquatic organisms have been found at the U.S. Army Atterbury Reserve Forces Training Area in Indiana (Risch, 2004) and in forage samples near the Atlantic Fleet Weapons Training Facilities near Puerto Rico (Diaz and Massol-Deya, 2003). In 1998, a cooperative study between the AK ARNG and the University of Alaska at Anchorage was conducted to determine whether expended ammunition on the firing ranges were causing lead or copper contamination in soils on the SRTA. The study indicated no lead or copper contamination at sample sites within the SRTA (Sveinbjornsson, 1998).

Purpose and Scope

This report summarizes streamflow, water-chemistry, and aquatic-habitat data collected during the summer of 2004 within the Stewart River Training Area. All data presented in this report will help establish a baseline data set and will provide insight into the quality of surface water within the SRTA. The streamflow and water-quality data collected during this study is archived in the USGS National Water Information System and can be retrieved at uniform resource locator http://nwis.waterdata.usgs.gov/ak/nwis.

Acknowledgments

The author gratefully acknowledges the assistance of Emerson Krueger of the Alaska Army National Guard Environmental Section in field work, providing data concerning the SRTA, and review of the project plan and this report. Larry Gough of the U.S. Geological Survey provided comparison trace-element data from the Nome area. Resources were also provided to the study by Tom Sparks of the Bureau of Land Management, Nome field office.

Environmental Setting

The terrain of the Seward Peninsula consists predominately of rolling hills, flat divides, and isolated groups of small glaciated mountains. The typically high gradient streams in the upland areas have eroded the landscape to form sharp, V-shaped valleys. These streams transition into slow meandering channels once they reach the coastal lowlands. Lakes and ponds in the upland areas are usually formed in bedrock or morainal areas, whereas low-land lakes are typically thaw lakes formed in depressions resulting from subsidence following local melting of ground ice in permafrost regions. The entire Seward Peninsula is underlain by permafrost, and there are no glaciers on the peninsula (Wahrhaftig, 1965).

The SRTA is near the southern coast of the Seward Peninsula in the foothills of the Kigluaik Mountains. The Stewart River Basin is a broad, glaciated valley bordered to the north, east, and south by rolling hills and small rounded mountains. Elevation in the basin ranges from 400 to 2,262 feet (ft). The short tributaries to the Stewart River have carved out small V-shaped valleys down the northern and southern slopes of the basin. The Stewart River is a moderate gradient, braided stream with a gravel and cobble alluvial channel. Vegetation in the SRTA ranges from a variety of willow species in stream floodplains to tundra throughout the valleys and mountain slopes. The Stewart River valley is dotted with several small ponds, many of which become dry by late summer or early fall. A moderately thick layer of permafrost throughout the SRTA influences many of the environmental features and processes within the area, including vegetation type, soil infiltration and drainage, accumulation of surface-water drainage, and the formation of marshes and tundra (Alaska Army National Guard, 2001).

Goldbottom Creek and the North Fork Snake River drain the southern side of the divide between the Stewart and Snake River drainages (fig. 2). To stay within the SRTA boundary, sampling sites for these two streams were at relatively high elevations (Goldbottom Creek, site 1, elevation is approximately 550 ft; and North Fork Snake River, site 2, elevation is approximately 650 ft) near the headwaters of each stream. The North Fork Snake River sampling site is in a high-gradient reach of the stream, with a channel composed of flat angular rocks that create a step-pool characteristic. The upper reaches of Goldbottom Creek can be characterized as a moderate gradient gravel and cobble alluvial channel. Both streams are tributaries to the Snake River, which flows through Nome to Norton Sound on the Bering Sea (fig. 1).

The three pond sites selected for sampling in this study are Unnamed Pond near Silver Creek upper Stewart River (site 5), Unnamed Pond near Josie Creek middle Stewart River (site 6), and Unnamed Pond near Durrant Creek lower Stewart River (site 7). The ponds near Silver Creek and near Durrant Creek have similar physical characteristics: They are each 1 to 5 ft deep, 300 to 600 ft long (in the spring), and are on large plateaus 25 to 50 ft in elevation above the Stewart River. Bed materials range from organic materials to gravels to large angular boulders. Unnamed Pond near Josie Creek, the middle pond of three sampled ponds, did not match many of the characteristics of the other two pond sites. Unnamed Pond near Josie Creek is a very small (approximately 50 ft wide by 200 ft long) and shallow (1.5 ft maximum depth) pond adjacent to the live firing ranges at the base of a short bluff. This pond is part of a larger marshy area along the banks of the Stewart River, and it is probably partially inundated during overbank flooding. The bed of Unnamed Pond near Josie Creek consists almost entirely of organic materials.

Climate

Climate in the Nome area is influenced by a combination of maritime and continental conditions. The area is subject to wide temperature variations throughout the year, with low humidity and low precipitation (Dorava, 1995). The average annual temperature is near -3 degrees Celsius (^{o}C), but temperatures can range from highs near 30^{o}C in the summer to lows below -45^{o}C in the winter. Mean annual precipitation in Nome is approximately 16 inches, with most rainfall occurring during the months of August and September. Average snowfall totals are approximately 55 inches per year.

Rainfall - Runoff Characteristics

Continuous precipitation data at the two streamgaging stations, Stewart River 0.1 mile below Boulder Creek mouth (site 3, table 1) and Stewart River 0.2 mile below Durrant Creek mouth (site 4), were collected every 15 minutes from May 2004 to September 2004, using tipping-bucket style precipitation gages. Precipitation values were measured and recorded in 0.01 inch increments at both stations. Data from the two gages were compared and correlated with precipitation data from the Nome Airport. The precipitation gage at Stewart River 0.1 mile below Boulder Creek mouth recorded numerous days of erroneously high values, presumably due to strong winds shaking the gage. The gage at Stewart River 0.2 mile below Durrant Creek mouth recorded a total of 6.56 inches of precipitation from May 27 to September 1, 2004, compared to 7.31 inches recorded at the Nome Airport. Daily precipitation totals for the gage at Stewart River 0.2 mile below Durrant Creek mouth and at the Nome Airport for the period May 27 to September 1, 2004 are shown in figure 3.

River stage data were collected continuously from late-May to early-September, 2004 at the USGS streamgaging stations, Stewart River 0.1 mile below Boulder Creek mouth near Nome (station number 15625850, site 3 on fig. 2) and Stewart River 0.2 mile below Durrant Creek mouth near Nome (station number 15625900, site 4).

Table 1. Water and bed-sediment sampling sites within the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

Site No. (from fig. 2)	USGS Station Number	Station Name	Drainage Area (square miles)
1	15619800	Goldbottom Creek near Nome, AK	1.37
2	15619900	North Fork Snake River near Nome, AK	1.55
3	15625850	Stewart River 0.1 mile below Boulder Creek mouth near Nome, AK	22.3
4	15625900	Stewart River 0.2 mile below Durrant Creek mouth near Nome, AK	53.2
5	644853165251800	Unnamed Pond near Silver Creek upper Stewart River near Nome, AK	--
6	644751165310400	Unnamed Pond near Josie Creek middle Stewart River near Nome, AK	--
7	644647165382100	Unnamed Pond near Durrant Creek lower Stewart River near Nome, AK	--

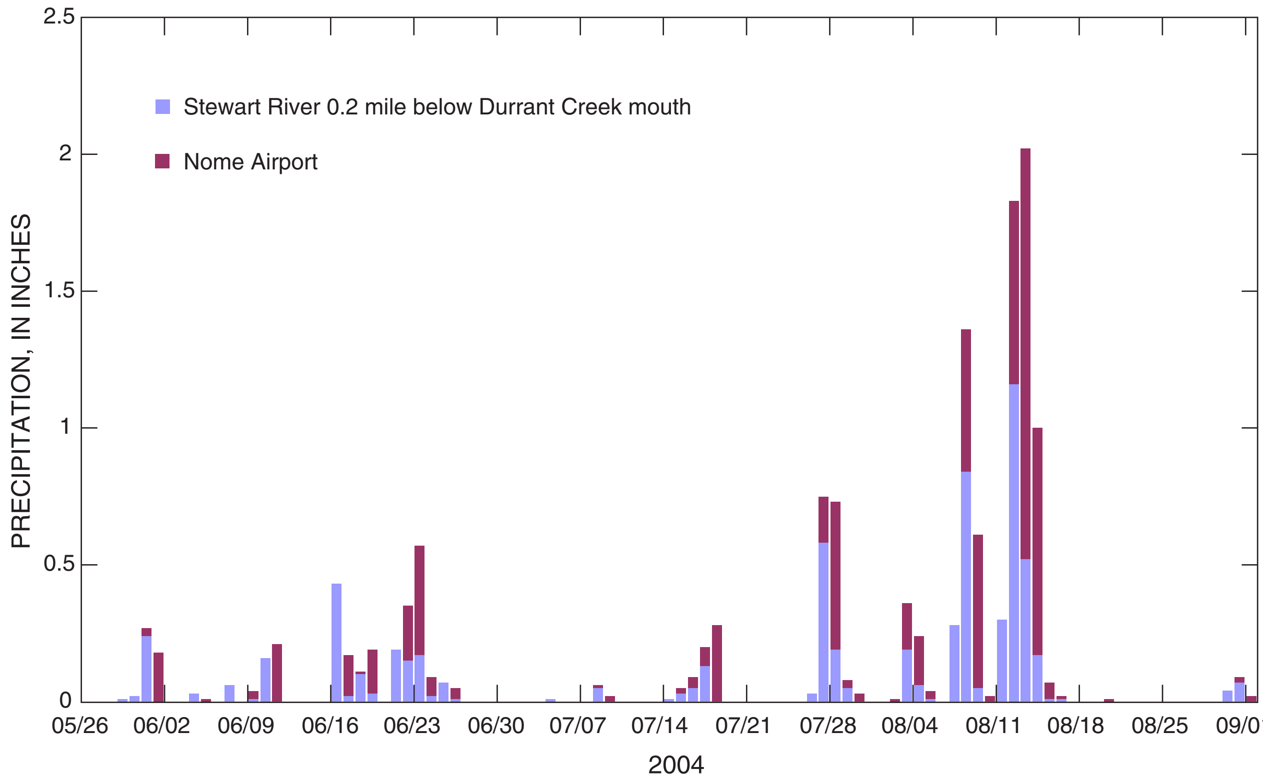


Figure 3. Daily precipitation totals at Stewart River 0.2 mile below Durrant Creek mouth near Nome and at Nome Airport, from May 28 to September 1, 2004.

Five discharge measurements were made at Stewart River 0.1 mile below Boulder Creek mouth (the upstream gaging station) and six discharge measurements were made at Stewart River 0.2 mile below Durrant Creek mouth (the downstream station), to develop stage-discharge relations. Discharges measured during the summer of 2004 ranged from 33.6 cubic feet per second (ft^3/s) to 218 ft^3/s at the upstream station and from 88.4 ft^3/s to 678 ft^3/s at the downstream station (table 2). Discharge measurements were made using methods outlined by Rantz and others (1982). Recorded stage data were used to compute daily mean discharge using methods outlined by Rantz and others (1982).

The upstream gaging station, Stewart River 0.1 mile below Boulder Creek mouth, drains an area of 22.3 square miles (mi^2), and the downstream gaging station, Stewart River 0.2 mile below Durrant Creek mouth, drains an area of 53.2 mi^2. The daily mean discharge at both gaging stations for the period May 26 to September 1, 2004 are plotted in figure 4. Maximum and minimum daily mean discharge by month, and mean monthly discharges for the period June to August, 2004 for the two gaging stations are shown in figure 5. Historically, streams in the Nome area reach their highest flows in August and September due to increased rainfall during these months, but 2004 was characterized by a very dry summer. However, the maximum instantaneous discharge computed from gage height data recorded at Stewart River 0.2 mile below Durrant Creek mouth was 760 ft^3/s on May 26 and 27, 2004, which occurred upon installation of the gaging station during the spring snowmelt peak. The maximum instantaneous discharge at Stewart River 0.1 mile below Boulder Creek mouth was 463 ft^3/s on August 12 and 13, 2004, in response to heavy rains in the upper part of the Stewart River basin. Although both stations were removed on September 1, 2004, it is unlikely that streamflows in September or October exceeded those recorded during station operation. Precipitation data from the Nome Airport do not indicate rainfalls during September or October that would equal or exceed those during August 2004.

Curran and others (2003) developed methods for estimating flood magnitude and frequency on ungaged or "under-gaged" sites in Alaska. Estimates of flood magnitude and frequency were calculated for both sites on the Stewart River (sites 3 and 4) on the basis of drainage areas and regional regression equations. Estimates from the regional regression equations were compared to computed discharges from the two gaging stations. Between May 27 to September 1, 2004, the computed peak discharge at Stewart River 0.1 mile below Boulder Creek mouth

Table 2. Discharge, physical properties, turbidity, and cyanide measured at sites within the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

[ft^3/s, cubic feet per second; µs/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L milligrams per liter; NTU, Nephelometric Turbidity Units; -- no data; < less than; N/A, not applicable]

Site No.	Station Name	Date	Discharge (ft^3/s)	Specific Conductance (µs/cm)	pH (standard-units)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Alkalinity (mg/L as $CaCO_3$)	Turbidity (NTU)	Cyanide (mg/L)
1	Goldbottom Creek near Nome	27-May-04	17.0	109	7.0	0.7	12.8	--	--	--
		22-Jun-04	4.9	281	8.1	8.0	--	--	4.4	<0.01
		23-Jun-04	--	250	8.0	7.5	11.4	--	--	--
		1-Sep-04	3.0	331	8.1	10.1	11.6	145	<2.0	<0.01
2	North Fork Snake River near Nome	27-May-04	17.8	90	7.4	1.6	13.4	--	--	--
		21-Jun-04	5.4	172	7.8	7.5	--	47	<2.0	<0.01
		28-Jul-04	--	199	7.6	10.0	10.5	--	--	--
		2-Sep-04	4.9	195	8.0	4.4	12.6	62	<2.0	<0.01
3	Stewart River 0.1 mi below Boulder Creek mouth	27-May-04	218	90	7.6	1.5	12.5	28	<2.0	<0.01
		28-Jul-04	33.6	216	7.4	11.5	10.3	80	<2.0	<0.01
		1-Sep-04	55.4	223	7.9	7.3	11.8	84	<2.0	<0.01
4	Stewart River 0.2 mi below Durrant Creek mouth	26-May-04	678	83	7.2	4.5	11.8	25	3.3	<0.01
		28-Jul-04	88.4	203	7.5	13.0	9.8	77	<2.0	<0.01
		1-Sep-04	109	220	7.8	8.8	11.0	83	<2.0	<0.01
5	Unnamed Pond near Silver Creek upper Stewart River	22-Jun-04	N/A	24	6.6	14.5	9.8	6	<2.0	<0.01
		29-Jul-04	N/A	35	6.9	17.5	9.7	7	<2.0	<0.01
6	Unnamed Pond near Josie Creek middle Stewart River	23-Jun-04	N/A	180	7.0	4.0	13.0	40	<2.0	<0.01
		29-Jul-04	N/A	173	6.5	6.0	13.5	32	<2.0	<0.01
7	Unnamed Pond near Durrant Creek lower Stewart River	22-Jun-04	N/A	10	5.9	15.0	10.2	2	2	<0.01
		29-Jul-04	N/A	13	5.9	17.0	9.5	3	<2.0	<0.01

(the upstream station) was 463 ft^3/s, which is between the 2-year flood magnitude estimate of 447 ft^3/s and the 5-year flood magnitude estimate of 706 ft^3/s. The estimated magnitude of a 100-year flood at this upstream station is 1,400 ft^3/s. The computed peak discharge at Stewart River 0.2 mile below Durrant Creek mouth (the downstream station) for the period May 26 to September 1, 2004, was 760 ft^3/s, which is below the 2-year flood magnitude estimate of 971 ft^3/s. The estimated magnitude of a 100-year flood at this downstream station is 2,900 ft^3/s. It should be noted that the regional regression equations used for estimating flood magnitudes and frequencies on the SRTA (the Arctic north and northwest Alaska region) are based on data from a small number of USGS gaging stations spread over a wide area, thus limiting their statistical validity (Curran and others, 2003).

Wiley and Curran (2003) developed equations for estimating low-duration flows for the months of July, August, and September for ungaged or under-gaged sites in Alaska. Regional regression equations, drainage areas, and mean annual precipitation were used to estimate monthly low-duration flow statistics for sites 3 and 4 on the Stewart River. These estimates were compared to a low-duration flow statistical analysis of computed mean daily discharges for the months of July and August for both gaging stations (table 3). Additional years of continuous discharge data on the Stewart River, and within this region, would strengthen the relationship between com-

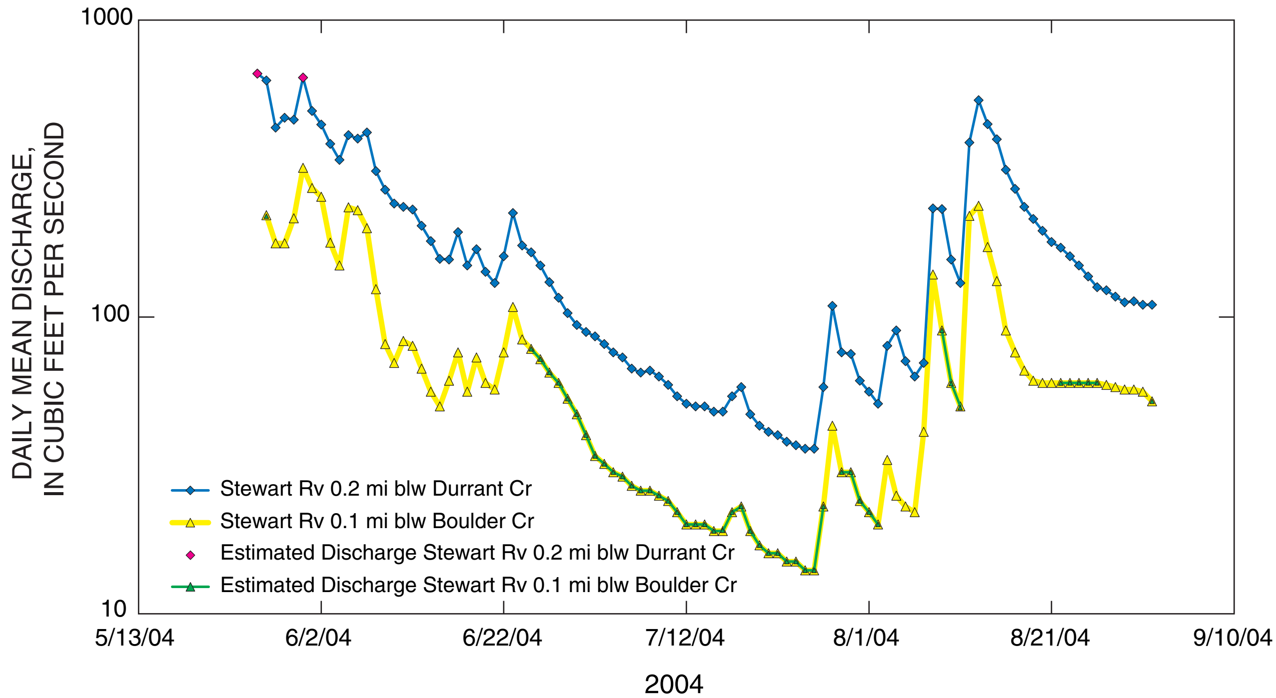


Figure 4. Daily mean discharge for Stewart River 0.1 mile below Boulder Creek mouth near Nome and Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska, from May 26 to September 1, 2004.

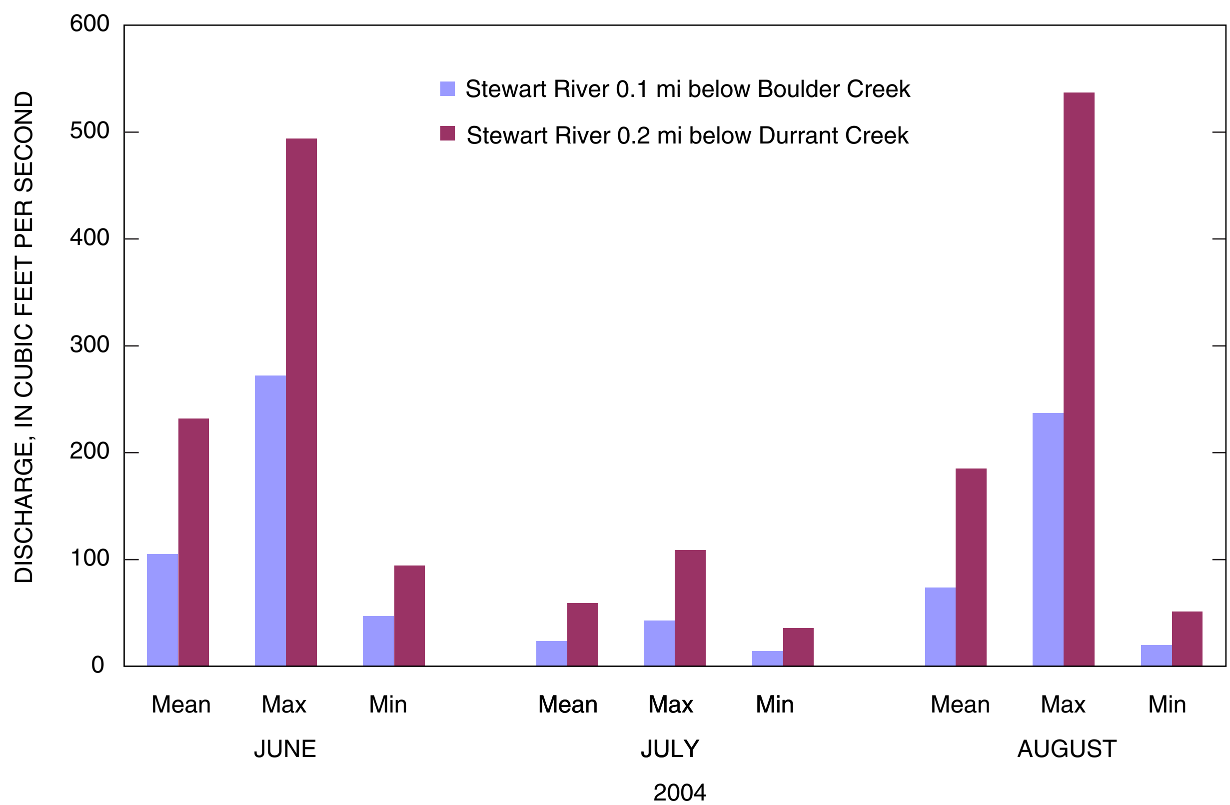


Figure 5. Maximum and minimum daily mean discharge by month, and mean monthly discharges for Stewart River 0.1 mile below Boulder Creek mouth near Nome and Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska, from June to August, 2004.

Table 3. Monthly low-duration flow statistics for July and August for stream-gaging stations Stewart River 0.1 mile below Boulder Creek mouth and Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska

Exceedance Probability, in percent	Monthly low-duration flow statistics using computed daily mean discharges from July and August, 2004				Monthly low-duration flow statistics using regional estimating equations			
	Daily mean discharge, in cubic feet per second							
	Stewart River below Boulder Creek		Stewart River below Durrant Creek		Stewart River below Boulder Creek		Stewart River below Durrant Creek	
	July, 2004	August, 2004	July, 2004	August, 2004	July	August	July	August
98	14.3	21.2	36.3	52.9	26.6	9.9	68.2	25.4
95	14.8	22.3	36.8	56.2	28.7	18.0	73.4	44.1
90	15.5	23.2	38.1	66.5	41.7	31.9	102	75.5
85	16.3	26.3	40.6	74.2	49.1	60.0	118	140
80	17.2	41.6	42.4	87.2	54.4	70.5	129	163
70	19.8	56.3	48.5	116	65.7	87.8	154	201
60	20.8	59.2	51.8	126	77.6	100	179	228
50	23.2	60.8	57.5	151	88.8	114	204	259

puted data from gaging stations and regional regression estimates. Mean annual precipitation for the Stewart River was determined to be 30 inches, based on the precipitation map of Jones and Fahl (1994) (available at http://ak.water.usgs.gov/Publications/pdf.reps/wrir93.4179.plate2.pdf or http://agdc.usgs.gov/data/usgs/water/statewide.html).

Regression equations for this region of Alaska (the Arctic north and northwest Alaska) were developed using data from a small number of USGS gaging stations spread over a wide area (Wiley and Curran, 2003). Standard errors of estimates of flow made using these equations can be quite large, but it is believed that the estimates calculated by these equations can still serve as a useful reference for flow conditions on the Stewart River during the summer of 2004.

Much of the water-stage data at Stewart River 0.1 mile below Boulder Creek mouth was affected by backwater from a beaver dam, which was constructed sometime after the station was installed on May 27, 2004. Because of the poor stage-discharge relation at the station, mean daily discharge values for much of 2004 were estimated. These estimates were made using hydrographic comparison between the two gaging stations on the Stewart River. Same day discharge measurements at both stations show a reliable relation between discharge at the upstream and downstream stations. The SRTA boundaries, backwater from the beaver dam, and braided channels prevented the selection of alternative sites for the upstream station.

In addition to the two gaging stations on the Stewart River, three miscellaneous discharge measurements were made at Goldbottom Creek (drainage area 1.37 mi^2) and at the North Fork Snake River (drainage area 1.55 mi^2). Measured discharge ranged from 17.0 ft^3/s on May 27, 2004 to 3.02 ft^3/s on September 1, 2004 at Goldbottom Creek, and from 17.8 ft^3/s on May 27, 2004 to 4.88 ft^3/s on September 2, 2004 at the North Fork Snake River (table 2).

Water Quality

Methods of Data Collection and Analysis

Field water-quality parameters (specific conductance, pH, water temperature, and dissolved oxygen) were measured at all seven sites. Samples of water and streambed sediment were collected at all sites and analyzed for major inorganic ions, total organic carbon, selected trace elements, and cyanide. Suspended sediment and turbidity were measured in samples from the stream sites. All sampling equipment was thoroughly cleaned prior to use with a non-phosphate laboratory detergent, rinsed in 5 percent hydrochloric acid, rinsed with deionized water, and rinsed with native water at each site prior to sample collection, following USGS protocols (Wilde and others, 1998). Depth-integrated water samples were collected at each stream using the equal width-increment method (Edwards and Glysson, 1998). Mid-depth water samples were collected on each pond at three points. Water samples were processed in Nome, usually within 6 to 8 hours after collection, using equipment and methods described by Wilde and others (2002). All water and bed sediment samples were sent to the USGS National Water-Quality Laboratory (NWQL) in Lakewood, Colorado, for analysis by standard USGS analytical methods (Fishman and Friedman, 1989; Patton and Truitt, 1992; and Fishman, 1993). Replicate water-quality and suspended sediment samples were collected and analyzed during the study, along with one field blank for quality control/quality assurance purposes. Water samples from the stream sites also were analyzed for concentration of suspended sediment by the USGS Sediment Analysis Laboratory in Vancouver, Washington.

A portable water-quality meter was used to measure cross-sectional values of dissolved-oxygen concentration, specific conductance, pH, and water temperature at the time of collection of each sample. Discharge measurements were made at all stream sites at the time of sampling, using methods outlined by Rantz and others (1982).

Bed sediment samples were collected from multiple depositional zones at each site. Sediments were collected from the surface of the streambed or pond bed using Teflon tubes, and were composited in glass bowls (Shelton and Capel, 1994). Two types of samples were obtained from this composite: a sample for analysis of total organic carbon (TOC) was passed through a 2-millimeter (mm) stainless-steel sieve; and a sample for analysis of trace elements was passed through a 0.063-mm Nylon sieve. Up to 250 milliliter (mL) of native water was used for sieving the trace-element sample. Water included in the trace-element sample was decanted after fine-grained sediments had settled. Samples for TOC were chilled after sieving.

Laboratory procedures used for processing bed sediment samples for trace element analysis are described by Arbogast (1990). Because a total digestion procedure was used to make these analyses, these data may be more useful for differentiating source areas of sediments than for detecting anthropogenic effects, or for determining bioaccumulation in fish.

Samples for analysis of bacteria were collected twice at all sites and three times at the Stewart River sites. Samples were collected from mid-stream in 500 mL sterile bottles and most samples were processed in Nome within 6 hours. Because of helicopter logistics, work load, and time constraints, the elapsed time between sample collection and processing exceeded 6 hours for some samples. All bacteria concentrations for this study were determined using the membrane-filter method following procedures outlined in the USGS National Field Manual for the Collection of Water-Quality Data - Biological Indicators (Myers and Wilde, 2003). Quality control/quality assurance procedures were used for all samples.

Results

Specific Conductance

The specific conductance of water quantifies its ability to conduct an electrical charge and is determined by the type and concentration of ions in solution (Hem, 1992). Specific conductance can be an indicator of the dissolved-solids or ion content in water. Values from the two sites on the Stewart River and the site on North Fork Snake River were similar, and ranged from 83 microsiemens per centimeter (µs/cm) to 223 µs/cm (table 2). Specific conductance at Goldbottom Creek ranged from 109 µs/cm to 331 µs/cm, indicating a greater dissolved mineral content than at the other stream sites. Low values of specific conductance in the spring reflect the runoff of snowmelt and increased stream flow, whereas higher values in late summer indicate a greater relative proportion of ground-water contribution to the flow of the stream. Specific conductance values for Unnamed Pond near Silver Creek upper Stewart River and Unnamed Pond near Durrant Creek lower Stewart River ranged from 10 µs/cm to 35 µs/cm. These low values indicate that the water in these two ponds is supplied almost entirely by rainfall or snowmelt runoff and not from ground water. Specific conductance values for Unnamed Pond near Josie Creek middle Stewart River were 173 µs/cm and 180 µs/cm, which supports the observed ground-water seepage from the adjacent hillside.

Hydrogen-Ion Activity (pH)

The measurement of hydrogen-ion activity, or pH, of water can range from 0 (very acidic) to 14 (very alkaline) standard units. A natural stream, free from contaminants, generally has a pH range of 6.5 to 8.5 standard units (Hem, 1992). Fish growth and survival depends on a pH from 6.5 to 9.0 standard units. Values of all sampled stream sites were within this range. Both samples from the pond near

Durrant Creek had pH values of 5.9 and one sample each from the ponds near Silver Creek and near Josie Creek had values near 6.5 (table 2). A study of tundra soils in the firing ranges of the SRTA reported acidic soils, with a pH range of 3.7 to 5.9 standard units (Sveinbjornsson, 1998). Water leaching through this acidic soil into an isolated body of water may help to explain why pH levels at the ponds were found more acidic. Also, waters derived from snowmelt or rainfall usually have low pH values.

Water Temperature

Water-temperature data were collected every 15 minutes at both gaging stations on the Stewart River (sites 3 and 4) from May to September 2004, using a submersible pressure/temperature transducer or an independent water temperature thermistor. Both sensors are accurate to within 0.5°C. Cross-sectional water temperature profiles were made near the transducer at the downstream station (site 4) to confirm that no temperature variation existed across the width of the stream.

Because of the presence of the beaver dam at the upstream station, Stewart River 0.1 mile below Boulder Creek mouth, cross-sectional water-temperature profiles were not made near that transducer, except for the first sampling date in May, prior to construction of the dam. Water temperature cross-sections were made downstream of the dam where the river returned to undisturbed flow conditions and better stream mixing. Cross-sectional water-temperature measurements at that point show no variation across the stream. Water temperatures measured continuously at the gaging station do not match cross-sectional averages, except for the May measurements prior to beaver dam construction. An independent water temperature thermistor was installed at the station in June to verify the reliability of the water temperature data collected by the submersible transducer. Water-temperature values collected in the gage/beaver dam pool area are lower than those from cross-sectional profiles downstream. During July, water temperatures at the transducer were 5.5°C lower than the average cross-sectional water-temperature (11.5°C), and in September water temperatures at the transducer were 3.5°C lower than the average water-temperature at the cross-section (7.5°C). These low temperatures suggest upwelling of ground water near the gaging station or possible influx of water from a small slough immediately upstream of the station. Recorded water temperature at Stewart River 0.1 mile below Boulder Creek mouth (the upstream station) represents only mean streamwater temperature for May 27 to June 5, 2004. All water-temperature data from June 6 to September 1, 2004, when the station was removed, are not representative of median stream water-temperatures because of the influence of the beaver dam.

Recorded water temperature for May 27 to September 1, 2004 at Stewart River 0.2 mile below Durrant Creek mouth (the downstream station) ranged from 0.5°C on May 27 to 18.5°C on July 22 and July 24. Recorded water-temperature at Stewart River 0.1 mile below Boulder Creek mouth (the upstream station) was not representative of median stream temperatures for June 5 to September 1, but cross-sectional water-temperatures measured downstream from the beaver dam ranged from 1.5°C on May 27 to 11.5°C on July 28. Daily mean and average cross-sectional water-temperatures at sites 3 and 4 for May 27 to September 1, 2004 are shown in figure 6.

Dissolved Oxygen

The concentration of dissolved oxygen in water is controlled by atmospheric pressure, air temperature, and water temperature. Elevated concentrations of dissolved oxygen can be the product of photosynthesizing biota and the hydraulic characteristics that determine the supply of oxygen, whereas depressed values of dissolved-oxygen concentrations can be the product of decomposition of organic matter (Hem, 1992). Fish maturation and survival depends upon well-oxygenated water throughout all stages in their life span. Concentrations of dissolved-oxygen at the four stream sites (sites 1 - 4) ranged from 9.8 mg/L (milligrams per liter) to 13.4 mg/L (table 2). Concentrations in the ponds near Silver Creek and near Durrant Creek were between 9.5 mg/L and 10.2 mg/L. The pond near Josie Creek had the highest measured dissolved-oxygen concentrations (13.0 mg/L and 13.5 mg/L). All sites sampled indicated well oxygenated waters with concentrations sufficient to support fish.

Alkalinity

Alkalinity is a measure of the capacity for solutes, within a solution, to neutralize acid. The alkalinity of most natural waters is produced by dissolved carbon dioxide species, bicarbonate and carbonate (Hem, 1992). Measured values of alkalinity are reported as equivalent concentrations of calcium carbonate ($CaCO_3$). Alkalinity values for the four stream sites (sites 1-4) ranged from 25 to 145 mg/L as $CaCO_3$ (table 2). Alkalinity values from samples at the ponds near Silver Creek and near Durrant Creek were between 2 to 7 mg/L as $CaCO_3$. The low

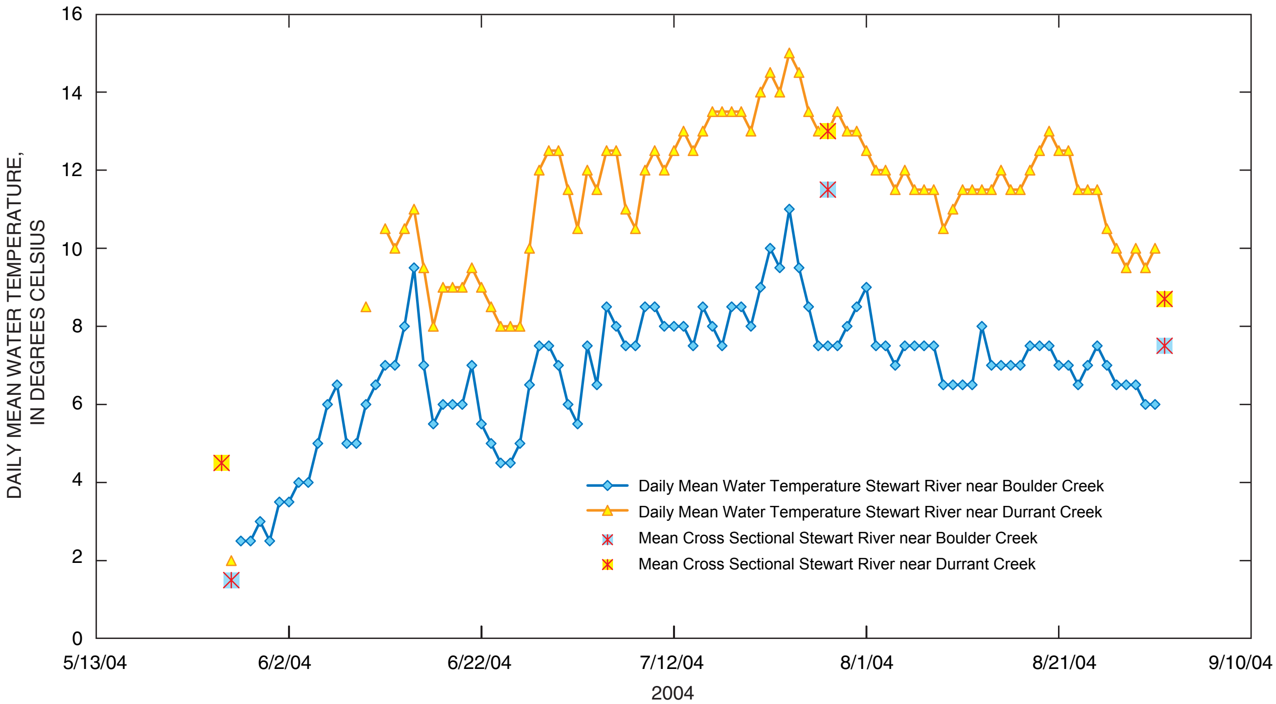


Figure 6. Daily mean water temperatures Stewart River 0.1 mile below Boulder Creek mouth near Nome and Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska, from May 27 to September 1, 2004.

alkalinity values at these ponds indicates a source contribution of rainwater or snowmelt runoff which is typically less than 10 mg/L (Hem, 1992) or transport through soils containing high amounts of organic carbon. Unnamed Pond near Josie Creek had values of 40 mg/L and 32 mg/L as $CaCO_3$. The alkalinity values at all sites indicate water with a low buffering capacity and limited availability of inorganic carbon. Because measured pH values at all of the sites were below 8.3 standard units, the alkalinity for all samples can be assigned to dissolved bicarbonate (Hem, 1992).

Turbidity

Turbidity is the measure of the optical properties that cause light rays to scatter or become absorbed within a volume of water. Because the presence of suspended and dissolved sediments, organic matter, and microscopic organisms are all potential causes of turbid waters, measurements of turbidity can lend insight into the sediment transport, ecological processes, and the overall condition of natural water systems (Gray and Glysson, 2003). For the growth and propagation of aquatic life, the Alaska Department of Environmental Conservation recommends that turbidity not exceed 25 Nephelometric Turbidity Units (NTU) above natural conditions in streams and not more than 5 NTU above natural conditions for all lake waters (Alaska Department of Environmental Conservation, 2003). Drinking water standards require turbidity below 5 NTU (U.S. Environmental Protection Agency, 2004). Sample analysis showed turbidity levels less than the minimum detection level of 2.0 NTU except for the high flow, spring runoff sample from site 4, Stewart River 0.2 mile below Durrant Creek mouth and the June 22 sample from Goldbottom Creek (table 2). Turbidity levels at sampling sites on the SRTA are within all recommended limits.

Cyanide

Cyanide is a naturally occurring inorganic substance that is derived from nitrogen and is stable in most natural aqueous solutions. Drinking water standards have limited the amount of cyanide allowed in water supplies since early in the 20th century, and the U.S. Environmental Protection Agency (EPA) listed cyanide as a “priority pollutant” in the late 1970s (Hem, 1992). Some forms of cyanide are toxic to both micro and macroorganisms. Cyanide commonly is associated with mining operations, as a potential by-product of gold extraction (U.S. Environmental Protection Agency, 2005). The occurrence of cyanide in natural waters is often associated with industrial waste (Sawyer and McCarty, 1967) and with certain types of large-scale gold mining operations (Johnson and others, 1998). The drinking water and recreational human health

Table 4. Major dissolved inorganic constituents measured in water samples collected within the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

[all values in milligrams per liter; --, no data; <, less than]

Site No.	Station Name	Date	Dissolved solids	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Silica
1	Goldbottom Creek near Nome	22-Jun-04	157	47.5	6.59	1.60	0.24	--	25.8	1.72	5.32
		1-Sep-04	196	61.3	8.29	1.74	0.20	176	30.0	1.61	6.09
2	North Fork Snake River near Nome	21-Jun-04	100	24.8	4.77	1.31	0.20	58	27.7	1.47	3.89
		2-Sep-04	104	27.3	5.96	1.47	0.17	76	32.8	1.34	4.58
3	Stewart River 0.1 Mi below Boulder Creek mouth	27-May-04	57	14.5	1.92	1.08	0.49	35	8.0	1.46	2.86
		28-Jul-04	149	36.2	5.24	2.21	0.95	97	29.1	1.51	7.49
		1-Sep-04	136	34.1	5.48	2.02	0.84	103	27.8	1.53	6.93
4	Stewart River 0.2 Mi below Durrant Creek mouth	26-May-04	53	12.3	1.88	1.03	0.38	31	7.7	1.52	2.66
		28-Jul-04	149	33.1	5.14	2.29	0.71	95	26.4	2.12	6.73
		1-Sep-04	130	37.3	5.68	2.20	0.62	101	26.5	1.88	6.96
5	Unnamed Pond near Silver Creek upper Stewart River	22-Jun-04	28	2.63	0.750	1.73	0.49	7	4.2	1.92	1.04
		29-Jul-04	33	2.79	0.811	2.06	0.68	8	4.9	2.12	0.77
6	Unnamed Pond near Josie Creek middle Stewart River	23-Jun-04	118	25.7	5.27	1.54	0.27	49	41.9	1.79	5.69
		29-Jul-04	99	19.9	3.85	1.57	0.19	40	32.8	1.79	6.14
7	Unnamed Pond near Durrant Creek lower Stewart River	22-Jun-04	14	0.33	0.192	1.10	0.29	3	0.4	1.27	0.86
		29-Jul-04	17	0.38	0.230	1.40	0.32	3	0.5	1.54	1.03

criterion standard for cyanide is 200 micrograms (µg/L) (U.S. Environmental Protection Agency, 2004). Cyanide concentrations were below the detection limit of 0.01 mg/L at all sampling sites on the SRTA (table 2).

Dissolved Solids and Major Ions

Water samples collected from all sites in the SRTA were analyzed for major ions and dissolved solids (table 4). Major ions and dissolved solids in natural waters are composed of inorganic minerals from filtration through soil and the erosion of rocks near the land surface (Hem, 1992). Therefore, concentrations of dissolved solids are typically highest in systems with soils and rocks that contain minerals that are easily dissolved. Concentrations of dissolved solids in all water samples collected within the SRTA indicate the presence of rock and soil source materials that do not contain easily dissolved minerals. Concentrations of dissolved solids at the two Stewart River gaging stations, at North Fork Snake River, and at Unnamed Pond near Josie Creek middle Stewart River ranged from 53 mg/L to 149 mg/L (table 4). Concentrations in samples from Unnamed Pond near Boulder Creek upper Stewart River and Unnamed Pond near Durrant Creek lower Stewart River ranged from 14 mg/L to 33 mg/L. Dissolved-solids concentrations at Goldbottom Creek ranged from 157 mg/L to 196 mg/L. The slightly higher values from Goldbottom Creek may indicate differences in rock and soil types, mineral exposure and dissolution, and a greater relative contribution of ground water to total streamflow than at other sampling sites within the SRTA.

Calcium is typically the predominant positively charged ion in most natural waters, followed by magnesium (Hem, 1992). Concentrations of calcium and magnesium in samples from North Fork Snake River, the two Stewart River gaging station sites, and the pond near Josie Creek ranged from 12.3 mg/L to 37.3 mg/L of calcium and 1.88 mg/L to 5.96 mg/L of magnesium (table 4). Calcium and magnesium concentrations in samples from the ponds near Silver Creek and near Durrant Creek ranged from 0.33 mg/L to 2.79 mg/L and 0.192 mg/L to 0.811 mg/L, respectively. At Goldbottom Creek, concentrations of calcium ranged from 47.5 mg/L to 61.3 mg/L and concentrations of magnesium ranged from 6.59 mg/L to 8.29 mg/L.

Sodium exists in all natural waters but is typically found in low concentrations in rivers (Hem, 1992). Concentrations of sodium in samples from all sites in the SRTA ranged from 1.03 mg/L to 2.29 mg/L, with little variation between the concentrations found at the stream sites from those at the pond sites (table 4). Natural waters also rarely contain high concentrations of potassium (Hem, 1992); concentrations of potassium were less than 1.0 mg/L at all sampling sites within the SRTA (table 4).

Bicarbonate concentrations in natural waters are usually within a moderate range, commonly below 10 mg/L in rain water and below 200 mg/L in most streams (Hem, 1992). Concentrations of bicarbonate were similar in samples from all stream sites at the SRTA (sites 1- 4) and at Unnamed Pond near Josie Creek, with values ranging from 31 mg/L to 176 mg/L (table 4). Bicarbonate concentrations in samples from the ponds near Silver Creek and near Durrant Creek ranged from 3 mg/L to 8 mg/L, which may indicate that these ponds are recharged primarily by snowmelt and rainfall runoff rather than by ground water inflow.

Natural sources of sulfate in aqueous solutions include erosion of rocks, volcanic input, and biochemical processes (Hem, 1992). Concentrations of sulfate were similar in samples from all four stream sites (sites 1 - 4) and from Unnamed Pond near Josie Creek middle Stewart River, with values ranging from 7.7 mg/L to 41.9 mg/L (table 4). Sulfate concentrations in samples from the ponds near Silver Creek and near Durrant Creek ranged from 0.4 to 4.9 mg/L (table 4).

Chloride is found in all natural waters, but typically in low concentrations (Hem, 1992). Concentrations of chloride in samples from all sites in the SRTA were similar, with values ranging from 1.27 mg/L to 2.12 mg/L (table 4).

Silica is derived from the weathering of soils and rocks, and concentrations in natural waters are usually between 1.0 mg/L and 30 mg/L (Hem, 1992). Concentrations of silica in samples from all stream sites (sites 1 - 4) and from Unnamed Pond near Josie Creek (site 6) ranged from 2.66 mg/L to 7.49 mg/L, and concentrations from the ponds near Silver Creek and near Durrant Creek ranged from 0.77 mg/L to 1.04 mg/L (table 4).

The concentrations of major ions in all water samples at the SRTA were converted to milliequivalents per liter so that the proportions of the major cations (calcium, magnesium, sodium, and potassium) could be plotted on one triangle of a trilinear diagram (fig. 7), similar to those developed by Piper (1944). The major anions were plotted on another triangle of the diagram and the data on these two triangles were extended to a diamond-shaped field. The trilinear diagram displays the chemical composition of multiple samples on a single graph, and allows determination of the overall composition of the water.

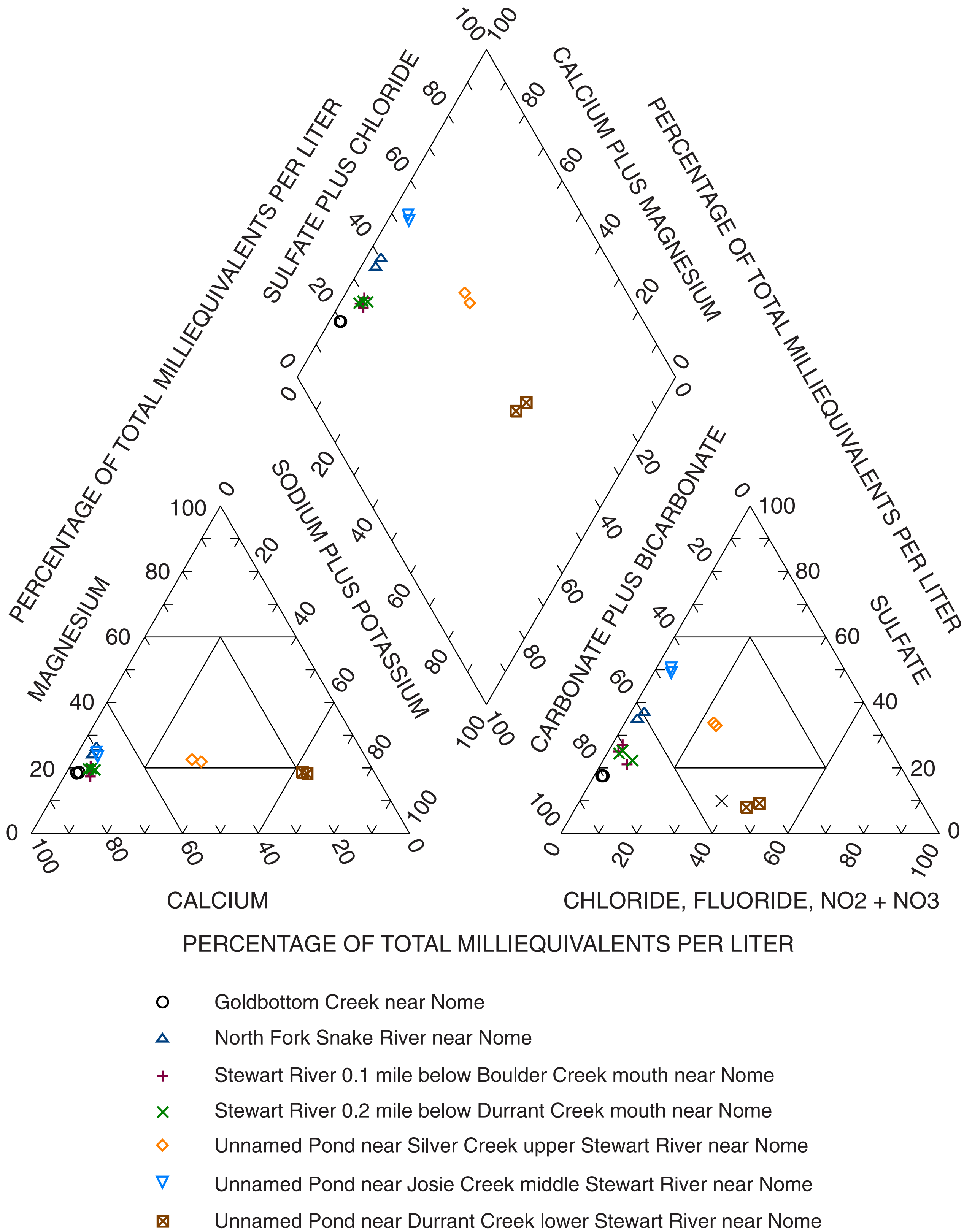


Figure 7. Chemical composition of water samples from seven selected sites in the Alaska Army National Guard Stewart River Training Area near Nome, Alaska.

On the basis of samples collected during this study, the water from all stream sites on the SRTA (sites 1 - 4) was classified as calcium bicarbonate, and the water of Unnamed Pond near Josie Creek middle Stewart River was classified as calcium sulfate bicarbonate (fig. 7). Samples from Unnamed Pond near Silver Creek upper Stewart River contained relatively similar concentrations of both cations and anions, and plotted near the center of all three diagrams; water in this pond near Silver Creek was classified as calcium sodium bicarbonate sulfate. Based on the samples collected at Unnamed Pond near Durrant Creek lower Stewart River, the water at this site was classified as sodium bicarbonate chloride. The classifications of the waters of the ponds near Silver Creek and near Durrant Creek further support the theory that the water in these ponds is derived primarily from direct snowmelt and rainfall runoff, thus minimizing the amount of transport through rocks and soils, and limiting the concentration of dissolved constituents in the water. This also is indicated by the more even distribution of major ion concentrations and a notable difference in classification than for other sampling sites on the SRTA.

Trace Elements

The source of trace elements is commonly the natural environment, but trace elements are subject to redistribution when rock or soils are disturbed or relocated. For this discussion, aluminum and iron, which are abundant elements, are considered trace elements because of their low concentrations in water. Although some trace elements are essential micronutrients at low concentrations, they can create a toxic environment at elevated levels. Concentrations of trace elements in water are usually much lower than those found in bed sediments. This is due to the tendency of trace elements to absorb to fine-grained sediment particles.

Samples of the water column and bed sediments were collected at all sampling sites in the SRTA during the summer of 2004 and analyzed for trace elements. Water-column samples were analyzed for 17 trace elements (table 5).

Comparison of concentrations of dissolved trace elements from sites in the SRTA to concentrations from published or known values in other studies (table 6) show that concentrations in the SRTA are within the normal ranges, with the exception of arsenic concentrations at Goldbottom Creek and at Unnamed Pond near Silver Creek upper Stewart River, and copper concentrations in one sample from the same pond. Samples from targeted areas near Nome suspected to contain high cadmium concentrations and collected in areas that were mineralized (Larry P. Gough, U.S. Geological Survey, written commun., 2004) also had dissolved trace element concentrations similar to those measured during this study. All cadmium values within the SRTA were less than 0.04 µg/L. Comparison of the dissolved trace element concentrations from the SRTA with known water-quality standards that have been established for the protection of aquatic life (table 7) (Smith and Huyck, 1999) indicate that no concentrations of the trace elements detected in samples from the SRTA exceeded concentrations of acute or chronic standards.

Bed sediments collected from all sites in the SRTA were analyzed for 38 trace elements (table 8). The following nine trace elements in bed sediments have been evaluated for their potential toxicity to aquatic organisms: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc (MacDonald and others, 2000), and selenium (Van Derveer and Canton, 1997). The concentrations of trace elements in samples of bed sediment from the SRTA were compared to concentrations detected in previous studies (table 9). The USGS National Water-Quality Assessment (NAWQA) program has collected approximately 1,000 bed sediment samples for trace-element analysis throughout the contiguous United States, Alaska, and Hawaii, of which approximately 250 samples represent non-urban forested areas (V. Cory Stephens, U.S. Geological Survey, written commun., 2004). The trace-element concentrations (in micrograms per gram, dry weight) in bed sediment from the SRTA were compared to median concentrations from the NAWQA forested sites (table 9).

The Canadian Council of Ministers of the Environment (1995) has established guidelines for some trace elements in unsieved bed sediments. These guidelines use two assessment values, (1) the lower value, called the "interim freshwater sediment quality guideline" (ISQG), indicates that concentrations below this value rarely produce adverse effects; and (2) the upper value, called the "probable effect level" (PEL), is the concentration above which adverse effects are expected to occur frequently. Because bed-sediment samples from the SRTA were analyzed for trace elements in sediments finer than 0.062 mm, the particle sizes in which trace element concentrations tend to be greatest, comparisons with the Canadian guidelines may overestimate the effects on aquatic organisms (Deacon and Stephens, 1998). However, it is believed that the PEL can still serve as a useful comparison when applied to results of the analyses of the SRTA bed sediment samples.

MacDonald and others (2000) developed sediment quality guidelines (SQGs) for eight trace elements, and

Table 5. Trace element concentrations measured in water samples collected during summer 2004 from seven sites within the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

[all values in micrograms per liter; E, estimated; <, less than; M, presence verified, not quantified]

Site No.	Station Name	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper
1	Goldbottom Creek near Nome	22-Jun-04	9	2.99	7.6	12	<0.06	<0.04	<0.8	0.191	0.6
		1-Sep-04	3	2.44	5.6	15	<0.06	<0.04	<0.8	0.206	0.5
2	North Fork Snake River near Nome	21-Jun-04	3	2.68	2.6	5	<0.06	<0.04	<0.8	0.070	0.4
		2-Sep-04	E1	3.00	2.4	6	<0.06	<0.04	<0.8	0.093	0.4
3	Stewart River 0.1 Mi below Boulder Creek mouth	27-May-04	7	1.09	2.0	5	<0.06	<0.04	<0.8	0.077	0.5
		28-Jul-04	2	1.20	3.1	14	<0.06	<0.04	<0.8	0.111	0.5
		1-Sep-04	2	1.30	2.9	12	<0.06	<0.04	<0.8	0.114	0.5
4	Stewart River 0.2 Mi below Durrant Creek mouth	26-May-04	8	0.52	1.6	5	<0.06	<0.04	<0.8	0.082	0.7
		28-Jul-04	3	0.90	2.7	13	<0.06	<0.04	<0.8	0.114	0.5
		1-Sep-04	3	0.94	2.3	12	<0.06	<0.04	E0.5	0.136	0.4
5	Unnamed Pond near Silver Creek upper Stewart River	22-Jun-04	34	<0.20	2.6	5	<0.06	<0.04	<0.8	0.127	2.3
		29-Jul-04	35	<0.20	4.2	5	<0.06	<0.04	<0.8	0.097	1.3
6	Unnamed Pond near Josie Creek middle Stewart River	23-Jun-04	M	<0.20	1.6	13	<0.06	E0.03	<0.8	0.133	0.5
		29-Jul-04	E 1	<0.20	2.2	13	<0.06	E0.03	<0.8	0.074	0.4
7	Unnamed Pond near Durrant Creek lower Stewart River	22-Jun-04	23	<0.20	E0.2	1	<0.06	<0.04	<0.8	0.032	E0.4
		29-Jul-04	20	<0.20	0.3	1	<0.06	<0.04	<0.8	0.030	0.4

Site No.	Station Name	Date	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Silver	Zinc
1	Goldbottom Creek near Nome	22-Jun-04	E6	<0.08	7.3	E0.01	<0.4	1.18	<0.2	0.8
		1-Sep-04	<6	<0.08	8.9	<0.02	<0.4	1.14	<0.2	E0.5
2	North Fork Snake River near Nome	21-Jun-04	<6	<0.08	E0.2	<0.02	<0.4	0.64	<0.2	1.3
		2-Sep-04	<6	<0.08	E0.1	<0.02	<0.4	1.31	<0.2	0.7
3	Stewart River 0.1 Mi below Boulder Creek mouth	27-May-04	60	<0.08	9.2	<0.02	<0.4	0.47	<0.2	1.2
		28-Jul-04	<6	<0.08	1.5	<0.02	E0.3	0.70	<0.2	E0.4
		1-Sep-04	E5	<0.08	2.3	<0.02	E0.2	1.17	<0.2	0.9
4	Stewart River 0.2 Mi below Durrant Creek mouth	26-May-04	137	<0.08	13.5	<0.02	<0.4	0.49	<0.2	2.1
		28-Jul-04	12	<0.08	3.5	<0.02	E0.2	0.73	<0.2	<0.6
		1-Sep-04	13	<0.08	6.8	<0.02	E0.2	1.25	<0.2	E0.4
5	Unnamed Pond near Silver Creek upper Stewart River	22-Jun-04	177	0.09	10.9	E0.01	<0.4	1.22	<0.2	1.9
		29-Jul-04	306	E0.06	9.6	E0.01	<0.4	0.92	<0.2	0.7
6	Unnamed Pond near Josie Creek middle Stewart River	23-Jun-04	39	<0.08	3.4	<0.02	0.4	0.99	<0.2	1.2
		29-Jul-04	17	<0.08	1	<0.02	E0.3	1.01	<0.2	0.7
7	Unnamed Pond near Durrant Creek lower Stewart River	22-Jun-04	78	<0.1	1.6	<0.02	<0.4	0.18	<0.2	0.7
		29-Jul-04	72	<0.08	1.3	<0.02	<0.4	0.19	<0.2	1.4

Table 6. Summary of dissolved trace element concentrations in water from previous studies compared to ranges of dissolved trace element concentrations in water samples collected during summer 2004 from seven sites in the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

[all values in micrograms per liter; E, estimated; <, less than; --, no data; M, presence verified, not quantified]

	Martin and Whitfield (1983)	Meybeck (1988)	Hem (1992)	Nome Area Gough (2004) (Provisional Data)	Goldbottom Creek (site no. 1)	North Fork Snake River (site no. 2)	Stewart River below Boulder Creek (site no. 3)	Stewart River below Durrant Creek (site no. 4)	Unnamed Pond near Silver Creek (site no. 5)	Unnamed Pond near Josie Creek (site no. 6)	Unnamed Pond near Durrant Creek (site no. 7)
Aluminum	50	40 +- 20	--	<2 - 132	3 - 9	E1 - 3	2 - 7	3 - 8	34 - 35	M - E1	20 - 23
Antimony	1	--	0.1-1	<0.3 - 66.3	2.44 - 2.99	2.68 - 3.00	1.09 - 1.30	0.52 - 0.94	<0.20	<0.20	<0.20
Arsenic	1.7	1 +- 0.5	0.1-1	<1 - 3.4	5.6 - 7.6	2.4 - 2.6	2.0 - 3.1	1.6 - 2.7	2.6 - 4.2	1.6 - 2.2	E0.2 - 0.3
Barium	60	--	10	3.2 - 23.1	12 - 15	5 - 6	5 - 14	5 - 13	5	13	1
Beryllium	--	--	0.1	<0.05	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Cadmium	0.02	--	0.1-1	<0.02 - 8.52	<0.04	<0.04	<0.04	<0.04	<0.04	E0.03	<0.04
Chromium	1	0.8 +- 0.3	0.1-1	<1 - 1.7	<0.08	<0.08	<0.08	<0.08 - E0.5	<0.08	<0.08	<0.08
Cobalt	0.2	0.1 +- 0.05	0.1	0.04 - 0.89	0.191 - 0.206	0.070 - 0.093	0.077 - 0.114	0.082 - 0.136	0.097 - 0.127	0.074 - 0.133	0.030 - 0.032
Copper	1.5	2 +-1	1 - 10	<0.5 - 0.9	0.5 - 0.6	0.4	0.5	0.5 - 0.7	1.3 - 2.3	0.4 - 0.5	E0.4 - 0.4
Iron	40	50 +- 30	--	<50 - 2480	<6 - E6	<6	E5 - 60	12 - 137	177 - 306	17 - 39	72 - 78
Lead	0.1	--	0.1-1	<0.05 - 19	<0.08	<0.08	<0.08	<0.08	E0.06 - 0.09	<0.08	<0.08 - <0.1
Manganese	8.2	10 +- 5	--	<0.2 - 166	7.3 - 8.9	E0.1 - E0.2	1.5 - 9.2	3.5 - 13.5	9.6 - 10.9	1 - 3.4	1.3 - 1.6
Mercury	--	--	0.1	--	E0.01 - <0.02	<0.02	<0.02	<0.02	E0.01	<0.02	<0.02
Molybdenum	0.5	0.8 +- 0.4	0.1-1	<2	<0.4	<0.4	E0.2 - <0.4	E0.2 - <0.4	<0.4	E0.3 - 0.4	<0.4
Nickel	0.5	0.4 +- 0.3	0.1-1	0.7 - 6	1.14	0.64 - 1.31	0.47 - 1.17	0.49 - 1.25	0.92 - 1.22	0.99 - 1.01	0.18 - 0.19
Silver	0.3	0.4 +- 0.2	0.1	<3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc	30	10 +- 5	1 - 10	1 - 924	E0.5 - 0.8	0.7 - 1.3	E0.4 - 1.2	E0.4 - 2.1	0.7 - 1.9	0.7 - 1.2	0.7- 1.4

Table 7. Water-quality standards for dissolved concentrations of selected trace elements for protection of aquatic life (Smith and Huyck, 1999)

[values in micrograms per liter]

Trace Element	Acute	Chronic
Aluminum	750	87
Antimony	9,000	1,600
Arsenic	360	190
Beryllium	130	5.3
Cadmium	3.9	1.1
Chromium (VI)	16	11
Copper	18	12
Iron		1,000
Lead	82	3.2
Mercury	2.4	0.012
Nickel	1,400	160
Silver	4.1	0.12
Zinc	120	110

Van Derveer and Canton (1997) developed guidelines for selenium. Two significant levels of concentration were established for each trace element, the threshold effect concentration (TEC) and the probable effect concentration (PEC). Concentrations below the TEC are not expected to adversely effect sediment dwelling organisms, and the PEC is the concentration above which toxicity is likely. MacDonald and others (2000) also developed a Mean PEC Quotient to quantify the toxicity of combined trace-element concentrations. The PEC quotient is determined by dividing the concentration of each trace element by its consensus-based PEC. The sums of the individual PEC quotients are then normalized to the number of PEC quotients that are calculated for each sediment sample. The PEC quotient is based on normalized values of organic carbon (1 percent dry weight) in the bed sediments. A mean PEC quotient value below 0.5 indicates the absence of toxicity and a value above 0.5 indicates the presence of toxicity conditions.

Analyses of bed-sediment samples collected at the two gaging stations on the Stewart River showed similar concentrations of trace elements. Concentrations of most of the priority pollutant trace elements–those for which sediment-quality guidelines have been established–were the same, or only slightly different, at the two stations (sites 3 and 4; table 10).

Concentrations of arsenic, copper, nickel, and zinc were equal to or above the median values determined for reference forested sites in the USGS NAWQA study (V. Cory Stephens, U.S. Geological Survey, written commun., 2004) (table 9). Cadmium concentrations were equal to or exceeded the NAWQA median values for all sites except Unnamed Pond near Durrant Creek, and chromium concentrations were exceeded at all sites except Unnamed Pond near Silver Creek (table 9). Concentrations of lead were equal to the NAWQA median values at Goldbottom Creek, and exceeded the NAWQA median values at North Fork Snake River and both sites on the Stewart River (sites 3 and 4). Mercury concentrations exceeded the NAWQA median values at North Fork Snake River. Concentrations of selenium were equal to or exceeded the NAWQA median values at all sites except Goldbottom Creek.

Arsenic concentrations in samples from all sites in the SRTA exceeded the PEL established by the Canadian Council of Ministers of the Environment (2003), except for the sample from Unnamed Pond near Durrant Creek, which did exceed arsenic ISQC limits (table 9). Cadmium concentrations were equal to or exceeded the ISQC at all sites except at Goldbottom Creek and at the pond near Durrant Creek. Chromium concentrations exceeded the ISQC at all SRTA sites, and the PEL also was exceeded at all sites except at the ponds near Silver Creek and near Durrant Creek. Copper concentrations exceeded the ISQC at all sites except at the ponds near Josie Creek and near Durrant Creek. Lead concentrations in the sample from the North Fork Snake River exceeded the ISQC. Zinc concentrations exceeded the ISQC at all sites except Unnamed Pond near Durrant Creek.

Arsenic concentrations exceeded the PEC, developed by MacDonald and others (2000), at all sites except for the pond near Durrant Creek, which contained concentrations above the TEC (table 9). Cadmium concentrations exceeded the TEC at North Fork Snake River and at Stewart River below Boulder Creek (sites 2 and 3). Chromium concentrations exceeded the TEC at all sites, and concentrations at North Fork Snake River (site 2) and both Stewart River sites (sites 3 and 4) exceeded the PEC. Concentrations of copper, nickel, and zinc were greater than the TEC at all sites except Unnamed Pond near Durrant Creek, which had concentrations of copper and zinc below the TEC. Lead concentrations exceeded the TEC only at North Fork Snake River. Nickel concentrations exceeded the PEC at the two sites on the Stewart River and at North Fork Snake River.

The mean PEC quotient was above the lower toxicity threshold of 0.5 at Goldbottom Creek and at North Fork Snake River, with values of 0.61 and 0.53, respectively (table 10). For the two sites (gaging stations) on the Stewart River, the mean

Table 8. Trace element concentrations measured in bed sediment samples from sites within the Alaska Army National Guard Stewart River Training Area near Nome, Alaska

[values reported in micrograms per gram and percent concentrations, dry weight; <, less than]

Site No.	Station Name	Aluminum (percent)	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cadmium	Cerium	Chromium	Cobalt
1	Goldbottom Creek near Nome	8.0	43	400	810	2.5	<1	0.4	77	97	24
2	North Fork Snake River near Nome	9.5	62	380	1100	3.7	<1	1.6	100	120	29
3	Stewart River 0.1 Mi below Boulder Creek mouth	8.1	22	300	1100	3.2	<1	1.6	93	120	26
4	Stewart River 0.2 Mi below Durrant Creek mouth	8.4	11	220	1100	3.2	<1	0.9	97	120	25
5	Unnamed Pond near Silver Creek upper Stewart River	8.6	1.1	210	880	2.5	<1	0.7	73	60	16
6	Unnamed Pond near Josie Creek middle Stewart River	7.6	1.9	75	1200	2.4	<1	0.6	69	100	9
7	Unnamed Pond near Durrant Creek lower Stewart River	8.0	1.1	15	990	3.2	<1	0.3	92	78	12

Site No	Station Name	Copper	Europium	Gallium	Gold	Holmium	Iron (percent)	Lanthanum	Lead	Lithium	Manganese
1	Goldbottom Creek near Nome	40	2	19	<1	1	5.3	39	24	42	800
2	North Fork Snake River near Nome	64	2	25	<1	1	6.1	61	54	53	1000
3	Stewart River 0.1 Mi below Boulder Creek mouth	49	2	20	<1	1	6.0	49	25	46	1800
4	Stewart River 0.2 Mi below Durrant Creek mouth	53	2	20	<1	1	5.9	51	29	48	1200
5	Unnamed Pond near Silver Creek upper Stewart River	39	2	20	<1	1	4.0	37	16	32	640
6	Unnamed Pond near Josie Creek middle Stewart River	35	2	19	<1	<1	3.6	39	20	46	270
7	Unnamed Pond near Durrant Creek lower Stewart River	27	2	20	<1	1	3.3	48	20	43	430

Table 9. Concentrations of selected trace elements in bed material from various studies

[values in micrograms per gram; <, less then; --, no data]

Trace Element	Median value from NAWQA Reference Forested Sites (number of samples varies between 241 and 262)[1]	Range or Mean Values from NURE Data in or adjacent to the SRTA (ten streambed samples from 1978)[2]	Sediment Quality Guidelines			
			Interim Freshwater Sediment Quality Guideline (ISQC)[3]	Probable Effect Level (PEL)[3]	Threshold Effect Concentration (TEC)[4]	Probable Effect Concentration (PEC)[4]
Arsenic	7	262	5.9	17	9.8	33
Cadmium	0.4	<5 - 8	0.6	3.5	0.99	5
Chromium	63	92	37.3	90	43.4	111
Copper	26	45	35.7	197	31.6	149
Lead	24	16	35	91.3	35.8	128
Mercury	0.07	--	0.17	0.486	0.18	1.06
Nickel	26	<15 - 67	--	--	22.7	48.6
Selenium	0.7	<5	--	--	[5]2.5	[5]4
Zinc	110	<40 - 397	123	315	121	459

Trace Element	SRTA Results (single sample at each site)							
	Goldbottom Creek (site 1)	North Fork Snake River (site 2)	Stewart River 0.1 Mile below Boulder Creek (site 3)	Stewart River 0.2 Mile below Durrant Creek (site 4)	Unnamed Pond near Silver Creek (site 5)	Unnamed Pond near Josie Creek (site 6)	Unnamed Pond near Durrant Creek (site 7)	Mean Values from SRTA data (sites 1 - 7)
Arsenic	400	380	300	220	210	75	15	229
Cadmium	0.4	1.6	1.6	0.9	0.7	0.6	0.3	0.9
Chromium	97	120	120	120	60	100	78	99
Copper	40	64	49	53	39	35	27	44
Lead	24	54	25	29	16	20	20	27
Mercury	0.04	0.08	0.04	0.04	0.03	0.03	0.03	0.04
Nickel	40	93	62	62	46	40	34	54
Selenium	0.6	1.8	1	1	0.9	2.3	0.7	1.2
Zinc	130	190	200	170	140	130	110	153

[1]V. Cory Stephens, U.S. Geological Survey, (written commun, 2004); NAWQA (National Water-Quality Assessment Program)

[2]Smith (2001) (NURE sample numbers: 425000, 425001, 425002, 425003, 425004, 425005, 425010, 425011, 425012, 425013); NURE (National Uranium Resource Evaluation), SRTA (Stewart River Training Area)

[3]Canadian Council of Ministers of the Environment (2003)

[4]MacDonald and others (2000)

[5]VanDerveer and Canton (1997)

Table 10. Concentrations of priority pollutant trace elements in streambed sediments finer than 0.063 mm in the Alaska Army National Guard Stewart River Training Area near Nome, Alaska, June to July, 2004

[Organic carbon in percent; As, arsenic; Cd, cadmium; Cr, chromium; Cu, copper; Pb, lead; Hg, mercury; Ni, nickel; Se, selenium; Zn, zinc; bold type indicates values exceed PEC (probable effect concentration) when normalized for organic carbon content; bold values of PEC quotient (0.50 or greater) indicate presence of toxic conditions]

Site No.	Site Name	USGS Station Number	As (in micrograms per gram, dry weight)	Cd	Cr	Cu	Pb	Hg	Ni	Se	Zn	Organic carbon (percent)	Mean PEC Quotient
1	Goldbottom Creek near Nome	15619800	400	0.4	97	40	24	0.04	40	0.6	130	2.7	**0.61**
2	North Fork Snake River near Nome	15619900	380	1.6	120	64	54	0.08	93	1.8	190	3.5	**0.53**
3	Stewart River 0.1 mi below Boulder Creek mouth	15625850	300	1.6	120	49	25	0.04	62	1.0	200	2.9	**0.50**
4	Stewart River 0.2 mi below Durrant Creek mouth	15625900	220	0.9	120	53	29	0.04	62	1.0	170	3.1	0.37
5	Unnamed Pond near Silver Creek upper Stewart River	644853165251800	210	0.74	60	39	16	0.03	46	0.9	140	4.4	0.23
6	Unnamed Pond near Josie Creek middle Stewart River	644751165310400	75	0.58	100	35	20	0.03	40	2.3	130	5.3	0.11
7	Unnamed Pond near Durrant Creek lower Stewart River	644647165382100	15	0.31	78	27	20	0.03	34	0.7	110	3.2	0.09

PEC quotients were equal to or less than the lower toxicity threshold: 0.50 at the upstream site, and 0.37 at the downstream site. The mean PEC quotient was below the lower toxicity threshold at all pond sites, with values of 0.23 at Unnamed Pond near Silver Creek, 0.11 at Unnamed Pond near Josie Creek, and 0.09 at Unnamed Pond near Durrant Creek.

Median values of the concentrations of trace-elements in bed-sediment samples collected at the SRTA during the summer of 2004 were similar to the median and ranges for trace-element concentrations in ten samples collected in the present day SRTA as part of the 1978 National Uranium Resource Evaluation (NURE) (Smith, 2001). Median concentrations of chromium and lead in samples collected at the SRTA in 2004 were slightly higher than those from the NURE program, but overall the results from both of these studies are similar (table 9). Comparisons of trace-element concentrations in sediments reported by the two studies should be viewed with caution, however, because the analyses in the NURE program were made on bulk coarse sediment samples, whereas the samples analyzed in the current (SRTA) study were of sediment particle sizes finer than 0.062 mm. Yet the NURE data are considered a useful resource despite the differences in sediment particle size because of the proximity of the sampling sites for the two studies. NURE program information and data can be retrieved at uniform resource locator (URL) http://pubs.usgs.gov/of/1997/ofr-97-0492/.

Bacteria

Escherichia coli (*E. coli*) is a fecal indicator bacteria that commonly is used to assess water quality. Fecal indicator bacteria are not typically disease causing, but may indicate the presence of several waterborne disease-causing organisms (pathogens). The concentration of fecal indicator bacteria also can be used as a measure of the sanitary quality of water for human contact or con-

Table 11. Concentrations of *E. coli* bacteria from seven selected sites within the Alaska Army National Guard Stewart River Training Area near Nome, Alaska, May to September, 2004

[concentrations in colonies per 100 milliliters; discharge in cubic feet per second; E, estimated; <, less than; N/A, not applicable]

Site No.	Station Name	Date	*E. coli* concentration	Discharge
1	Goldbottom Creek	22-Jun-04	E1	4.9
		1-Sep-04	E2	3
2	North Fork Snake River	21-Jun-04	<1	5.4
		2-Sep-04	<1	4.9
3	Stewart River 0.1 mi below Boulder Creek mouth	27-May-04	E1	218
		28-Jul-04	64	34
		1-Sep-04	E5	55
4	Stewart River 0.2 mi below Durrant Creek mouth	26-May-04	E4	680
		28-Jul-04	40	89
		1-Sep-04	E8	109
5	Unnamed Pond nr Silver Creek Upper Stewart River	22-Jun-04	3	N/A
		29-Jul-04	E15	N/A
6	Unnamed Pond near Josie Creek Middle Stewart River	23-Jun-04	<1	N/A
		29-Jul-04	E4	N/A
7	Unnamed Pond near Durrant Creek Lower Stewart River	22-Jun-04	<1	N/A
		29-Jul-04	E5	N/A

sumption. The presence of *E. coli* in water is one of the preferred indicators of contamination from warm-blooded animals and therefore the possible presence of pathogens. The EPA's freshwater *E. coli* standard for primary contact in recreational waters is 126 colonies per 100 milliliters (colonies/100mL) (U.S. Environmental Protection Agency, 1986) and the detection of even 1 colony/100mL is cause for concern in drinking waters (Myers and Wilde, 2003). The only fecal indicator bacteria that the Alaska Department of Environmental Conservation currently lists in its water-quality standards is fecal coliform. Fecal coliform bacteria concentrations were not analyzed during this study.

Results of *E. coli* analysis of water samples collected at seven sites within the SRTA during the summer of 2004 indicate that all concentrations were well below standards established for safe human contact. Concentrations at all sites ranged from below detectable limits (<1 colony/100mL) to 64 colonies/100mL (table 11). Bacteria samples were collected and analyzed three times at the main stem Stewart River sites (sites 3 and 4). The high flow spring runoff sample and the early-fall sample contained very low counts, whereas the low-flow sample in July contained the highest concentrations (64 colonies/100mL at Stewart River 0.1 mile below Boulder Creek mouth) of the sampled sites. Bacteria samples were collected and analyzed twice at the other five sites (sites 1-2 and 5-7); concentrations were found to be below limits for proper analysis (<20 colonies/100 mL) or below detectable limits for all samples. Contributing factors to the presence of the bacteria could include large herds of reindeer observed near the river, as well as moose, musk-ox, bear, beavers and a variety of other animal and bird species.

Suspended Sediment

Sediment is transported in rivers in suspension and as bedload. Suspended sediments are typically fine particles such as clay, silt, and fine sand. Bedload sediments consist of larger particles, such as, sands, gravels, and even boulders that are transported along or near the streambed. A direct correlation exists between the size of a particle that can be transported and the turbulence of the flowing water. Increasing turbulence in flowing waters increases the potential for sediment transport.

Three samples for analysis of suspended sediment were collected at each of the four stream sites (sites 1-4) at the SRTA. Table 12 lists concentrations of suspended sedi-

Table 12. Concentrations of suspended sediment in water samples from stream sites within the Alaska Army National Guard Stewart River Training Area near Nome, Alaska, May to September, 2004

[--, no data, <, less than]

Site No.	Station Name	Date	Discharge (ft^3/s)	Suspended Sediment (mg/L)	Suspended Sediment (tons/day)	Suspended Sediment (percent finer than <0.063 mm)
1	Goldbottom Creek near Nome	27-May-04	17.0	30	1.4	60
		22-Jun-04	4.9	14	0.19	88
		1-Sep-04	3.0	1	0.01	--
2	North Fork Snake River near Nome	27-May-04	18.0	1	0.05	--
		21-Jun-04	5.4	1	0.01	52
		2-Sep-04	4.9	0.2	<0.01	--
3	Stewart River 0.1 mi below Boulder Creek mouth	27-May-04	218	3	1.80	74
		28-Jul-04	34.0	5	0.45	--
		1-Sep-04	55.0	0.4	0.06	--
4	Stewart River 0.2 mi below Durrant Creek mouth	26-May-04	680	13	24	87
		28-Jul-04	89.0	1	0.24	--
		1-Sep-04	109	0.3	0.09	--

ment reported in the units of milligrams per liter, tons per day, and the percent of grain sizes finer than 0.063 mm, when applicable. Suspended-sediment concentrations at these four sites were relatively low. Suspended sediment in samples from Stewart River 0.2 mile below Durrant Creek mouth ranged in concentration from 13 mg/L for the high flow spring runoff sample to <1 mg/L for the September sample. Suspended-sediment concentrations at Stewart River 0.2 mile below Boulder Creek mouth ranged from 3 mg/L for the high flow spring runoff sample, before the construction of the beaver dam, to 5 mg/L for the July low-flow sample, and <1 mg/L for the September sample (a replicate suspended sediment sample collected with the July sample reported a concentration of 4 mg/L). In July, the suspended-sediment concentrations at Stewart River 0.1 mile below Boulder Creek mouth may have been influenced by large numbers of spawning salmon upstream of the sampling cross section. Suspended-sediment concentrations for the North Fork Snake River were low and did not exceed 1 mg/L. Suspended-sediment concentrations at Goldbottom Creek ranged from 30 mg/L for the spring runoff sample to 14 mg/L for the July sample, to 1 mg/L for the September sample.

Elevated suspended-sediment concentrations at Goldbottom Creek may be partially attributable to the presence of an old access trail that pre-dates AK ARNG use. This trail crossed into and followed the streambed at the remnants of an old camp or abandoned mining operation (Jensen’s Camp, fig. 2) near the headwaters of Goldbottom Creek, approximately 0.5 mile upstream from the sampling site. The gradual erosion of stream banks and disruption of bed sediments at the trail crossing, along with possible runoff from mining operations at the camp, may be contributing to the higher sediment concentrations. The AK ARNG has rerouted the current trail around Goldbottom Creek to prevent any further disruption to the creek (Alaska Army National Guard, 2001). Stream bank erosion at trail crossings and increased suspended sediment loads are potential impacts of increased SUSV / ATV activity within the training boundary.

Physical Habitat Characteristics of Stewart River

Data on the physical habitat were collected at the two sites on the Stewart River - 0.1 mile below Boulder Creek mouth and 0.2 mile below Durrant Creek mouth - to define stream characteristics at the upstream and downstream boundaries of the SRTA. Data were collected following a subset of stream assessment protocols developed for the USGS NAWQA Program (Fitzpatrick and others, 1998). Characterization of each reach included surveys of channel

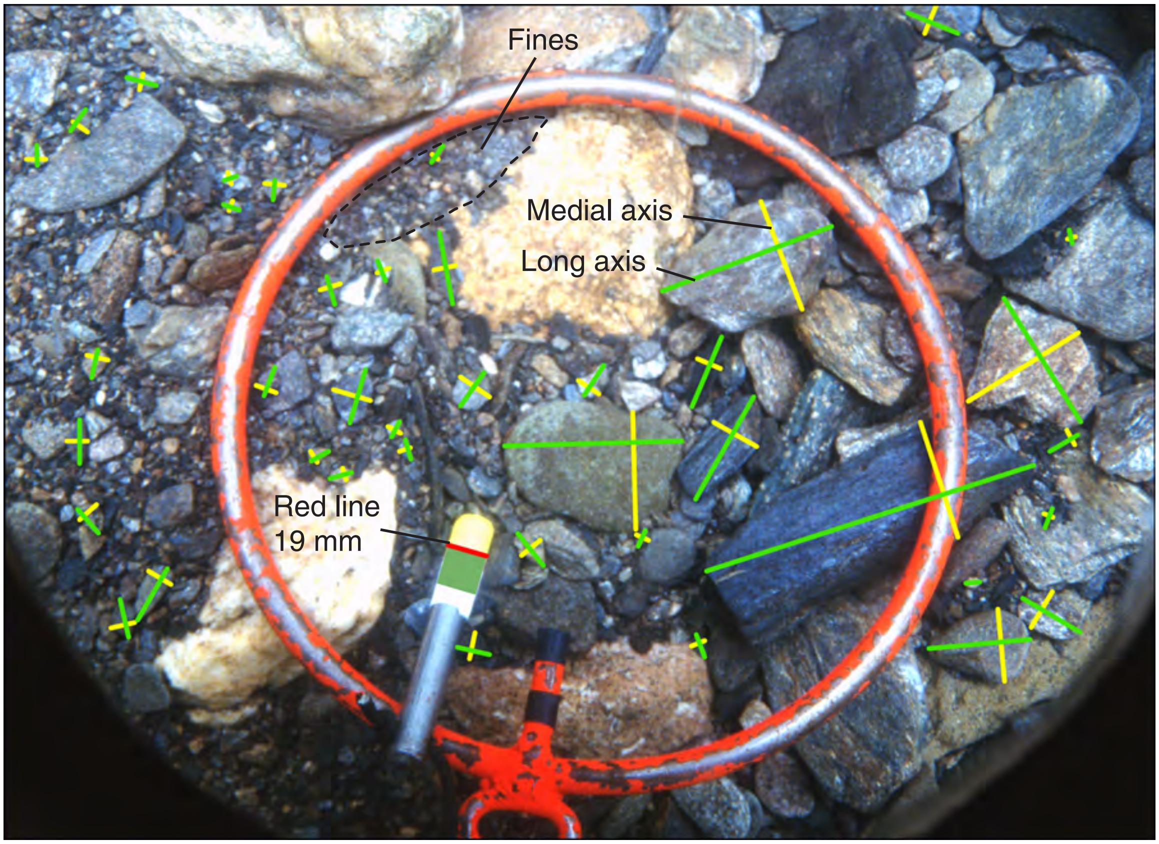


Figure 8. Example of a digitized streambed image from a sample point at Stewart River 0.1 mile below Boulder Creek mouth near Nome, including pebbles, medial axis, long axis, fines, and a scale polygon. (Photograph by Daniel A. Long, U.S. Geological Survey).

geometry, measurements of channel dimensions and flow velocity, determination of streambed composition, and observation of riparian conditions and features. Eleven equally spaced transects were surveyed at each study reach (appendix 3). Data collected at each transect included those on habitat type and cover, wetted-channel width, flow aspect (appendix 1), bank erosion, water-depth and point-velocity measurements, among others (appendix 2). Geomorphic channel units for this study included runs, pools, and riffles. Transect spacing and wetted-channel width were surveyed for distance and elevation relative to an arbitrary datum (appendix 3). Flow aspect is the direction of flow as observed from mid-channel at a particular transect with respect to the compass referenced to true north. Habitat cover for the study areas was defined by overhanging vegetation, undercut banks, woody debris, and boulders. Photographs of the right bank, left bank, and upstream and downstream views were taken at each transect.

Streambed particle sizes were determined using photographic techniques designed to characterize coarse (>2-mm) and fine (<2-mm) particle sizes (fig. 8)(Whitman and others, 2003). Photographs were taken of streambed substrate for particle size analysis at three points, including the thalweg (the deepest point of the transect), for each of the 11 cross sections. The photographs were incorporated into a Geographic Information System (GIS) format and particles shown in each photograph were digitized. Only completely exposed, non-embedded, coarse (>2 mm) particles or areal extents of fine-grained sediments (<2-mm) were digitized. Measurements of the digitized coarse particles were made along the intermediate (medial) axis by first determining the longest axis of a particle, and then digitizing the widest part normal (perpendicular) to the long axis. A separate magnification constant was calculated for each photograph by including a scale bar in each (Whitman and others, 2003). The medial axis measurement was then used to calculate ϕ (phi), which is a “base 2 logarithmic scale” commonly used to represent grain size in sediment distribution:

$$\phi = -\log_2 d = -(\log_{10} d / \log_{10} 2)$$

(where d = the medial axis)

Figure 9. Physical habitat study reach of Stewart River 0.1 mile below Boulder Creek mouth near Nome. (Photograph by Daniel A. Long, U.S. Geological Survey).

Particle-size measurements were reported in three percentiles (16th, 50th, and 84th) for each site and labeled as "D-values" (D16, D50, and D84). Sand-size and finer material was digitized as a polygon (area). In cases where the bed was completely covered with sand, the entire area was digitized, and the actual area was determined based on the constant derived from the length of the scale bar in the photograph.

The advantages of this type of analysis include minimal streambed disturbance, easy sample archiving, improved accuracy, and the potential to replicate the study (Whitman and others, 2003). All photographs are archived in geodatabases at the USGS Alaska Science Center Water Resources office in Anchorage, Alaska. Archived photographs allow for all analysis to be reviewed and replicated, and are available as a resource for additional studies.

Stewart River 0.1 mile below Boulder Creek mouth near Nome, Upper Stewart River

The Stewart River 0.1 mile below Boulder Creek study reach (fig. 9) is approximately 4 miles (mi) downstream from the headwaters of the Stewart River, and 0.5 mi inside the eastern boundary of the SRTA (site 3 on fig. 2). The study reach was approximately 508 ft long with transects numbered from TR1 at the downstream end of the reach to TR11 at the upstream end (fig. 10). This reach is composed of riffles, runs, and pools (Appendix 1).

The most upstream transect of this reach was surveyed approximately 100 ft below the gaging station to exclude the effect of a large beaver dam immediately downstream of the gage pool. The beaver dam created backwater and disrupted flow patterns upstream and directly downstream of the dam. Therefore, transects were placed outside the area directly affected by the dam to better represent typical stream characteristics for most of the upper reach of the Stewart River.

The Stewart River 0.1 mile below Boulder Creek reach was surveyed July 29, 2004. Physical characteristics are shown in appendixes 1, 2, and 3. The surveyed reach had flow aspects ranging from 194° at transect 4 to 265° at transect 11 (appendix 1). Stream bank vegetation was predominantly a variety of willow species and moist tundra [see the Stewart River Training Area Integrated Natural Resource Management Plan (Alaska Army National Guard, 2001) for more information on vegetation

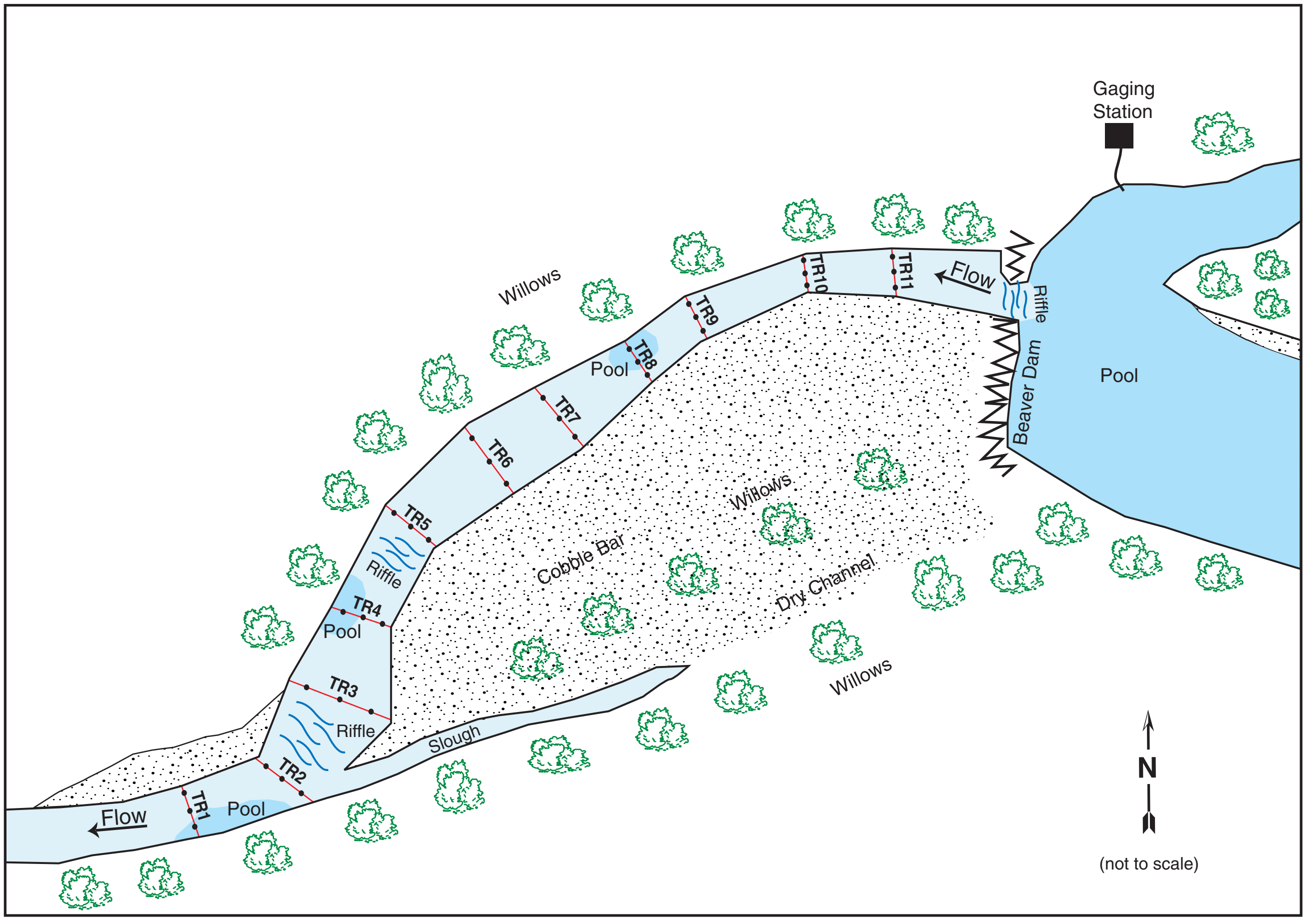


Figure 10. Major geomorphic features of Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska, July 24, 2004.

in the training area]. Undercut banks, woody debris, and overhanging vegetation provided instream habitat cover. Bed substrate ranged in size from sand (<2 mm) to small cobbles (>64-128 mm), but consisted predominantly of fine to medium gravels (>2-16 mm).

Photographic analysis of particle sizes at Stewart River 0.1 mile below Boulder Creek mouth revealed relatively clean gravels, with only 10 percent of the total area sampled covered by fine sediments. This resulted in fewer embedded or obstructed particles and allowed for 897 individual pieces of gravel to be digitized. Figure 11 shows the percentile distribution of particle sizes from both Stewart River sampling sites (sites 3 and 4). The particle sizes from both sites follow a log-normal distribution, typical of streambed sediments. The upstream site had more of the larger particle size class than did the downstream site. Particle-size analysis determined the following D-values for Stewart River 0.1 mile below Boulder Creek: D16= 4 mm, D50= 8 mm, and D84= 21 mm, i.e., 84 percent of all particles analyzed were finer than 21 mm.

Stewart River 0.2 mile below Durrant Creek mouth near Nome, Lower Stewart River

The Stewart River 0.2 mile below Durrant Creek mouth study reach (fig. 12) is approximately 2.5 mi upstream from the mouth of Stewart River and 0.5 mi inside the western boundary of the SRTA (site 4 on fig. 2). The study reach was approximately 820 ft long with transects numbered from TR1 at the downstream end of the reach to TR11 at the upstream end (fig. 13). This reach was composed of one long run and one riffle at transect 1 (appendix 1). The gaging station was between transects TR2 and TR3.

The Stewart River 0.2 mile below Durrant Creek mouth reach was surveyed July 28, 2004. Physical characteristics are shown in appendixes 1, 2, and 3. The surveyed reach had flow aspects ranging from 259° at transect 11 to 302° at transect 1 (appendix 1). Stream bank vegetation was predominately a variety of willow species, moist tundra, and sedge grasses. Undercut banks, overhanging vegetation and boulders provided instream habitat cover. Bed substrate

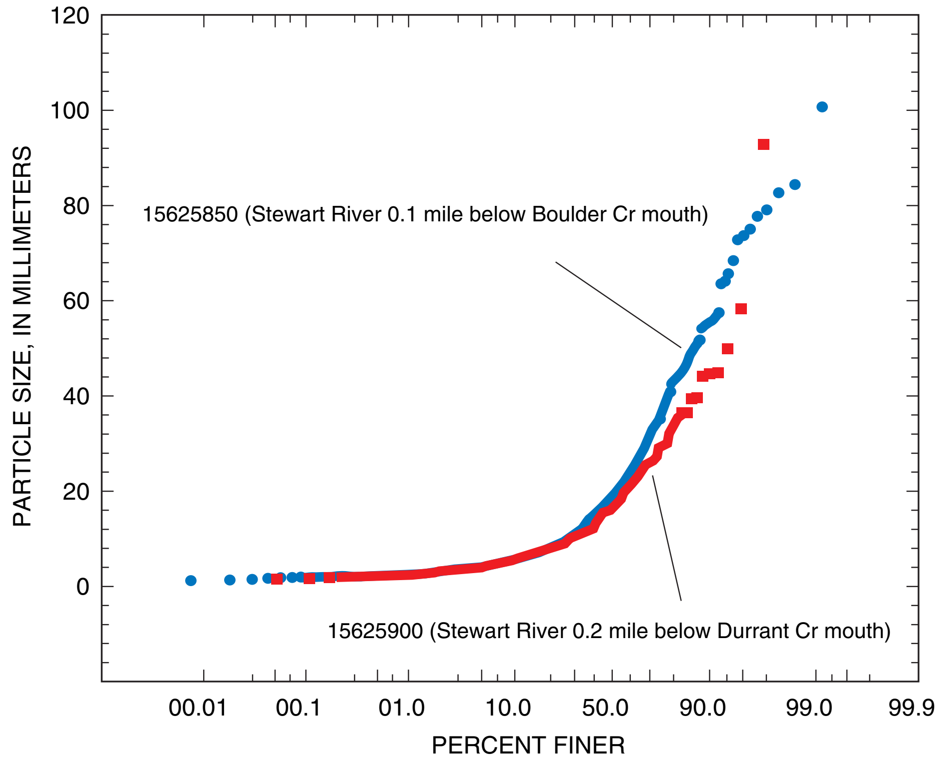


Figure 11. Distribution of particle sizes in bed sediment from Stewart River 0.1 mile below Boulder Creek mouth and Stewart River 0.2 mile below Durrant Creek mouth.

Figure 12. Physical habitat study reach of Stewart River 0.2 mile below Durrant Creek mouth near Nome. (Photograph by Daniel A. Long, U.S. Geological Survey).

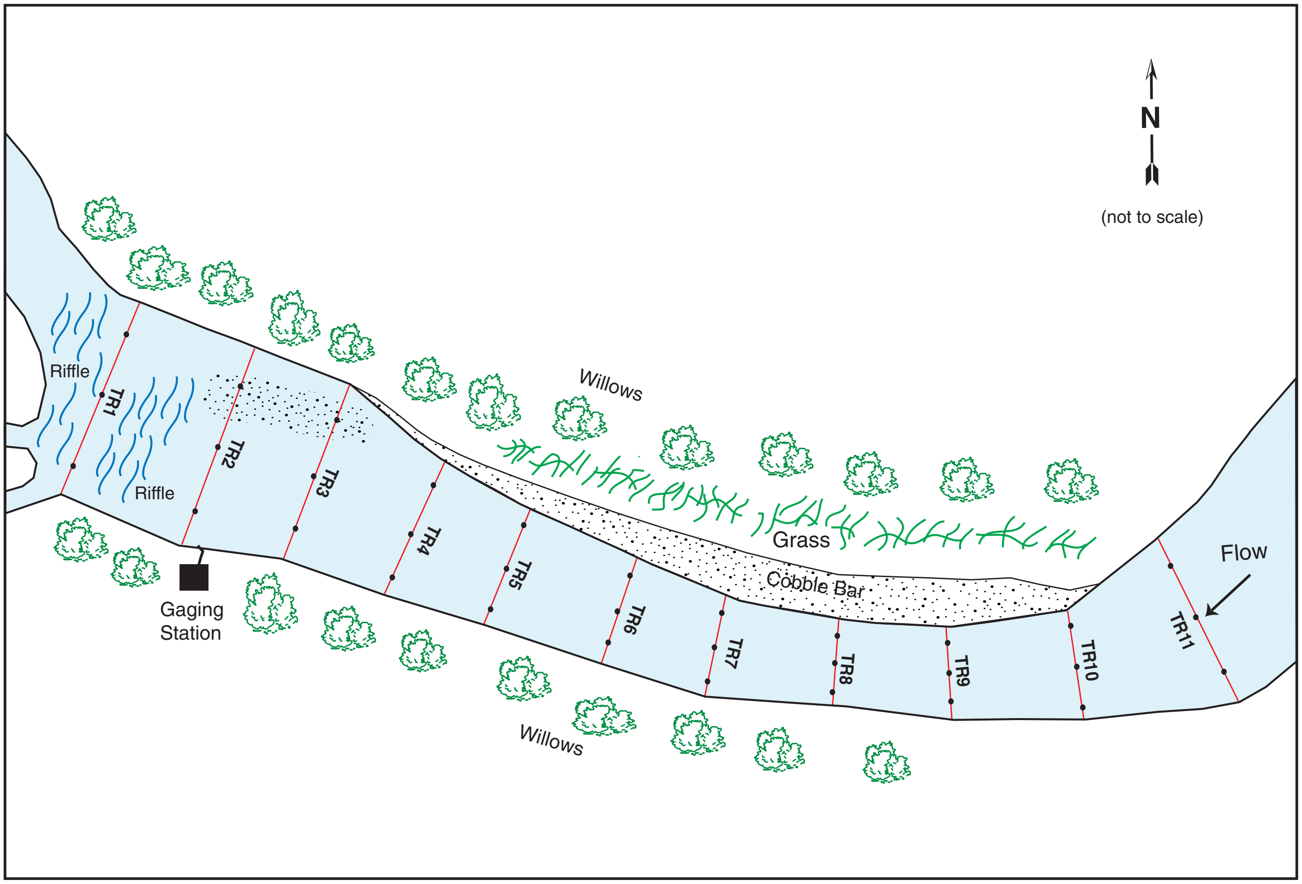


Figure 13. Major geomorphic features of Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska, July 28, 2004.

ranged in size from sand (<2 mm) to large boulders (>512 mm), but consisted predominantly of fine sediments (<2 mm).

A total of 254 individual particles were digitized at Stewart River 0.2 mile below Durrant Creek (site 4) mouth due to the abundance of fine sediments and algae, which embedded or obstructed the larger particles. More than 60 percent of the total sample area, from all 11 cross sections, was covered by fine sediments (<2 mm). The particle-size distribution of this downstream site on the Stewart River exhibits a shift toward an increasing percentage of finer material (fig. 11), indicating a preponderance of smaller particles suitable for digital analysis. The upstream site (site 3) had a greater number of larger particles compared to the smaller number of large particles at this downstream site (due in part to a greater number of large particles embedded or obstructed). Particle-size analysis determined the following D-values for Stewart River 0.2 mile below Durrant Creek: D16= 4, D50= 8 mm, and D84= 19 mm. Both sites on the Stewart River are relatively similar with respect to particle size at the 16th and 50th percentiles, but differ at the 84th percentile. The downstream site, however, contained a much larger percentage of fines than the upstream site, which showed a tendency toward larger particles. A qualitative analysis of the photographs of the streambed at Stewart River 0.2 mile below Durrant Creek mouth suggests the occurrence of larger particles, but the fine material tends to bury them, thereby eliminating them from quantitative analysis. Photographic analysis of the bed material at Stewart River 0.2 mile below Durrant Creek mouth after high streamflows of spring breakup may provide a more complete picture of the overall population of gravels and larger particles.

Summary and Conclusions

As part of an ongoing monitoring process to assess the potential environmental impacts of AK ARNG training activities, local mining, and vehicle usage at the SRTA near Nome, a cooperative study was initiated between the AK ARNG and the USGS. Water-quality and hydrologic data, and information on the physical habitat, were collected at seven surface-water sites within the SRTA during the summer runoff months (late May to early September) in 2004. The objectives of the study were to assess the quality of surface-waters within the SRTA, collect baseline surface-water data to be used as reference for future studies, and to enable comparison of the water-quality of Stewart River into and out of the training area.

The baseline data collected during this study did not include measurements or samples from a specific rainfall run off event nor winter measurements and sampling under ice. The high-flow samples from this study were collected during the spring snowmelt runoff peak rather than a rainfall peak. Because of the potential for concentrations of dissolved constituents and suspended sediment to differ during periods of heavy rainfall or icecover, this data set may not be representative of water-quality conditions throughout a typical year.

Analyses of data collected during the summer of 2004 indicate the following water-quality conditions at the SRTA:

- Measurement of field parameters at Unnamed Pond near Josie Creek indicated a wide variation in water-quality conditions at different points within that pond and chemical characteristics that differ from those at the other two ponds–Unnamed Pond near Silver Creek and Unnamed Pond near Durrant Creek. Ground water leaching through the tundra and entering one side of the pond (near Josie Creek) from the nearby hillside was visible during visits, and a small tributary stream to the Stewart River appears to contribute flow to the marshy area around the pond. Analysis of water-quality parameters and constituents suggest that the other ponds are recharged primarily by direct rainfall and snowmelt runoff, rather than by ground-water infiltration. Low concentrations of dissolved constituents in the water of the ponds near Silver Creek and near Durrant Creek suggest that these waters had minimal transport time through rocks and soils before entering the ponds. Water levels at these ponds receded rapidly during mid to late summer after all remaining snow had melted and prior to periods of consistent rainfall.

- Analyses of water samples for concentrations of dissolved chemical constituents, bacteria, and suspended sediment, and analyses of particle sizes in bed sediment at the two gaging stations on Stewart River - at 0.1 mile below Boulder Creek mouth and 0.2 mile below Durrant Creek mouth - indicate similar water-quality conditions and streambed properties at the two sites. Concentrations of most water-quality constituents collected during the summer of 2004 did not exceed standards for drinking water or recreational contact.

- Analysis of the concentrations of trace elements in bed sediment indicate the TEC as exceeded for arsenic, chromium, and nickel concentrations at all sample sites in the SRTA, and concentrations of copper and zinc exceeded the TEC at all sites except Unnamed Pond near Durrant Creek lower Stewart River. Cadmium concentrations were found to be above the TEC at North Fork Snake River and at Stewart River 0.1 mile below Boulder Creek mouth. Lead concentrations exceeded the TEC at North Fork Snake River. The PEC was exceeded by arsenic concentrations at all sites except Unnamed Pond near Durrant Creek, whereas chromium and nickel concentrations exceeded the PEC at Stewart River 0.1 mile below Boulder Creek mouth and at North Fork Snake River. Mean PEC quotients were equal to or less than the lower toxicity threshold at all sites except Goldbottom Creek and North Fork Snake River.

- Physical habitat characterization of the channel reaches at the two streamgaging stations on the Stewart River showed similar particle sizes in bed sediment at the two sites. The percentage of fine particles (<2 mm) at the downstream site (below Durrant Creek mouth) was much greater, however, than the percentage of fine particles at the upstream site (below Boulder Creek mouth).

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Appendixes

Appendix 1. Selected geomorphological channel units and instream physical characteristics at the two streamgaging stations on the Stewart River near Nome, Alaska, July, 2004.

[ft, feet; º, degrees]

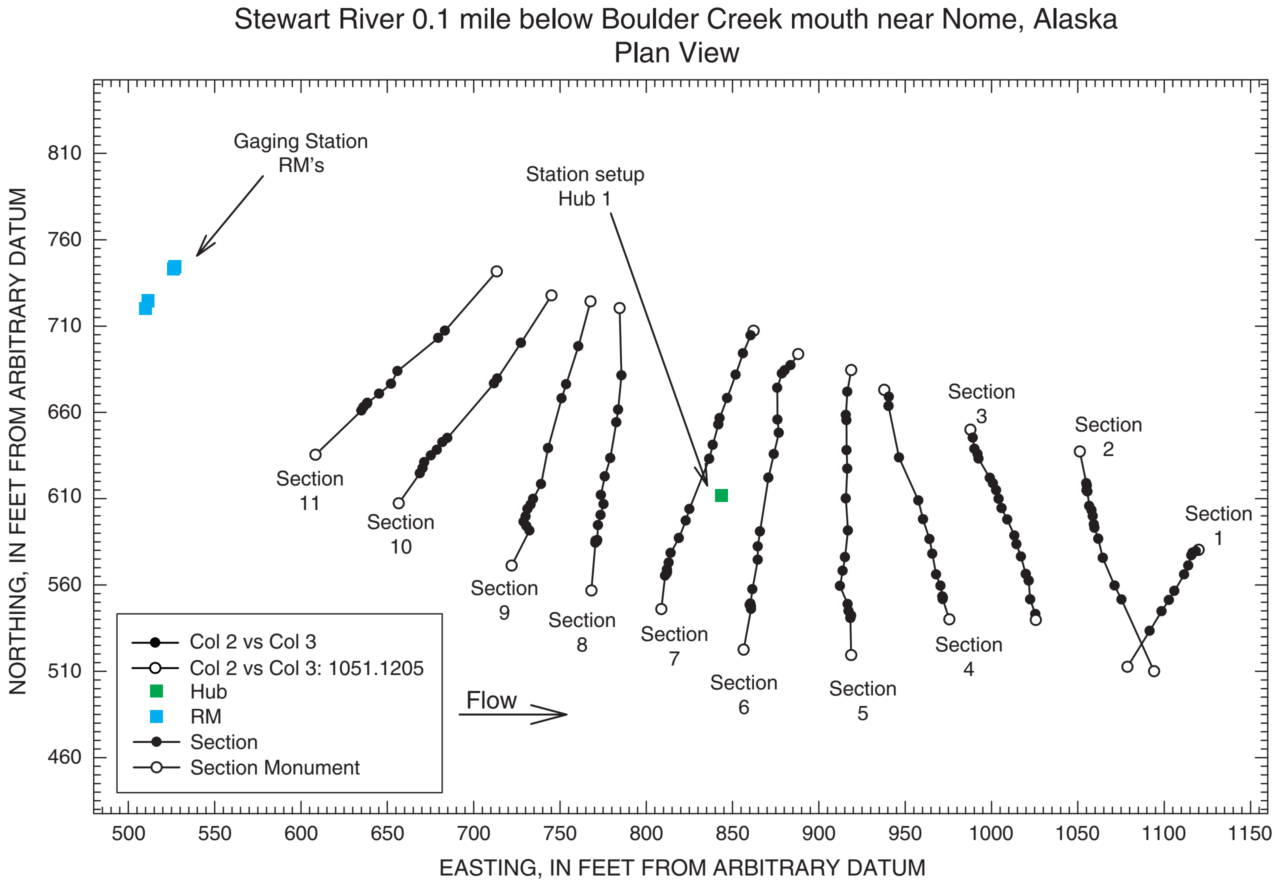
Station Name	Transect	Habitat Type	Wetted Channel Width (ft)	Bank Full Width (ft)	Flow Aspect (º)
Stewart River 0.1 mile below Boulder Creek mouth near Nome, AK 15625850	1	pool	28.9	60	255
	2	riffle	40.2	114	253
	3	riffle	60.0	112	206
	4	run	34.7	118	194
	5	pool	34.1	62	214
	6	run	42.9	141	218
	7	run	37.4	148	255
	8	run	27.0	43	237
	9	pool	24.1	67	229
	10	run	19.4	97	251
	11	run	25.9	77	265
Stewart River 0.2 mile below Durrant Creek mouth near Nome, AK 15625900	1	riffle	140.0	141	302
	2	run	142.0	145	293
	3	run	126.0	130	296
	4	run	99.0	130	292
	5	run	84.6	112	283
	6	run	75.0	105	290
	7	run	70.4	114	288
	8	run	58.0	117	281
	9	run	62.6	158	276
	10	run	74.9	143	263
	11	run	126.0	177	259

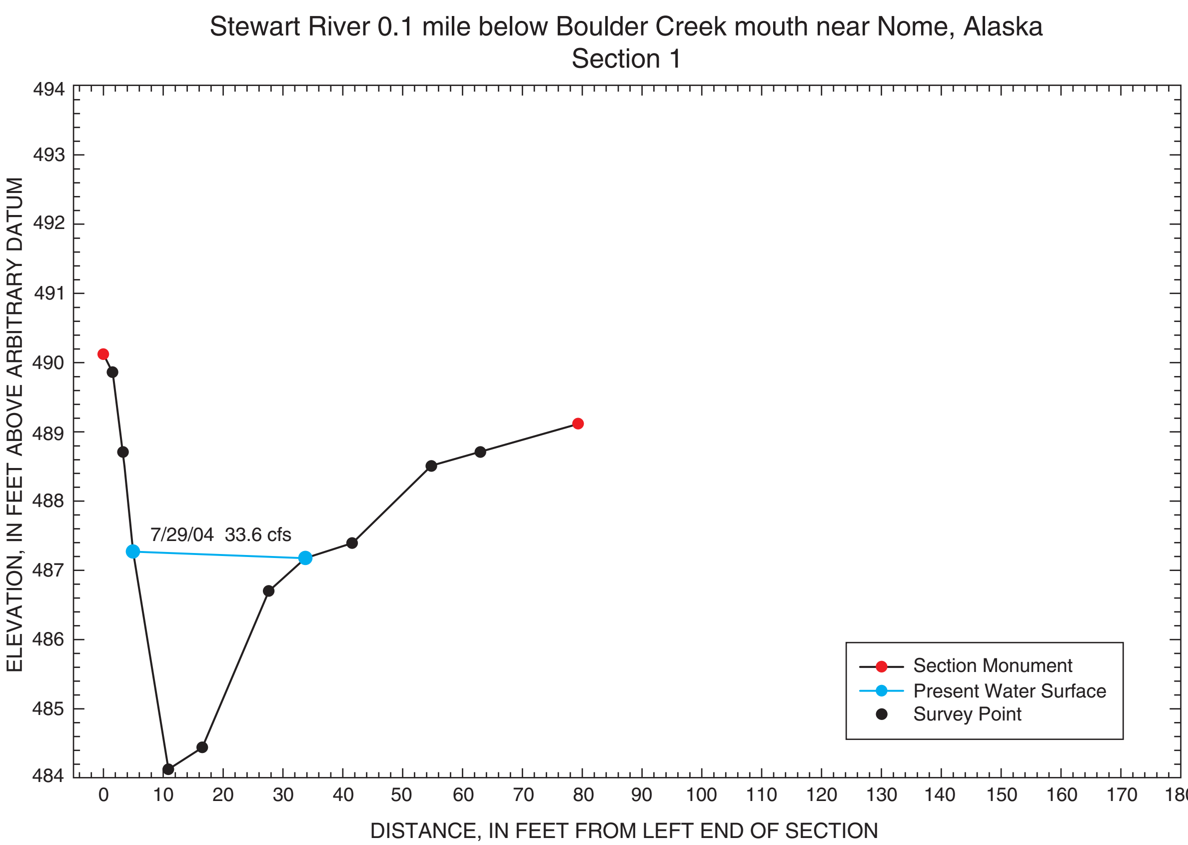
Appendix 2. Selected physical and habitat characteristics at the two streamgaging stations on the Stewart River near Nome, Alaska, July, 2004.

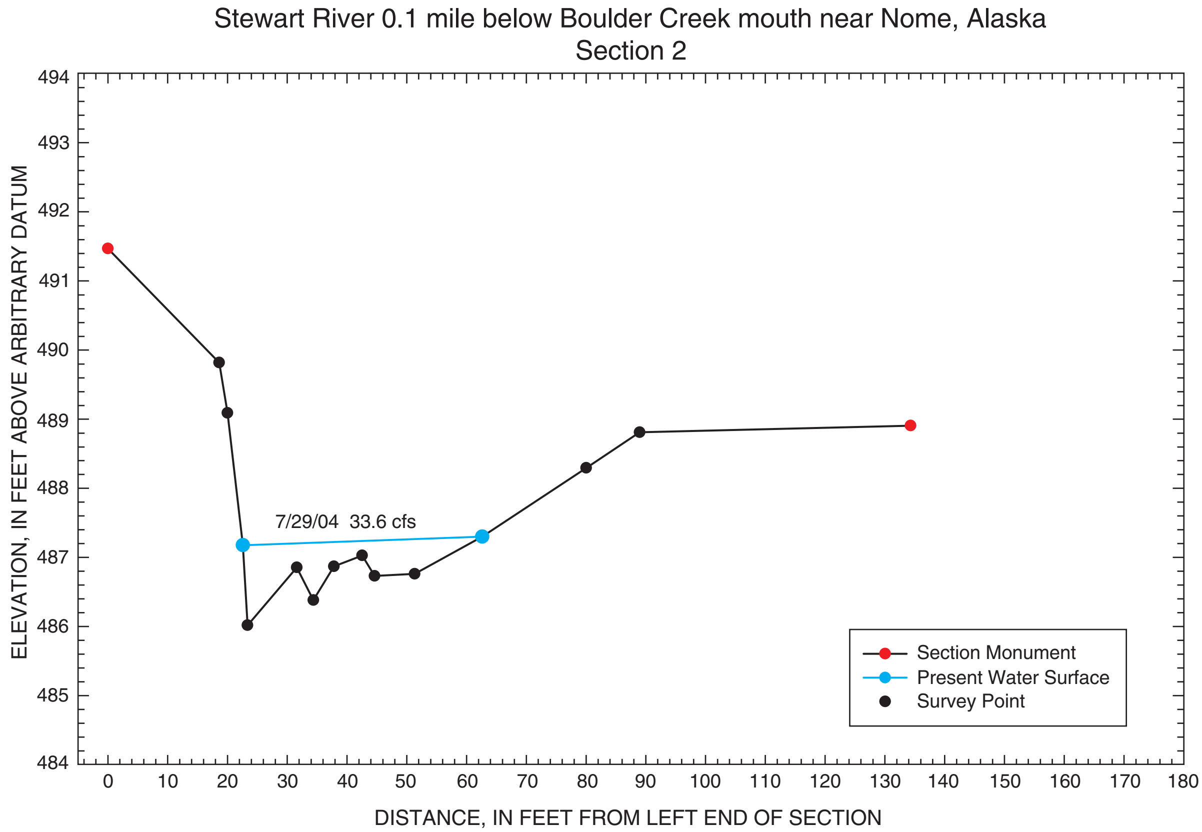
[ft, feet; ft/s, feet per second; mm, millimeters; ft^3/s, cubic feet per second; Y, yes; N, no; LEW, left edge of water; REW, right edge of water]

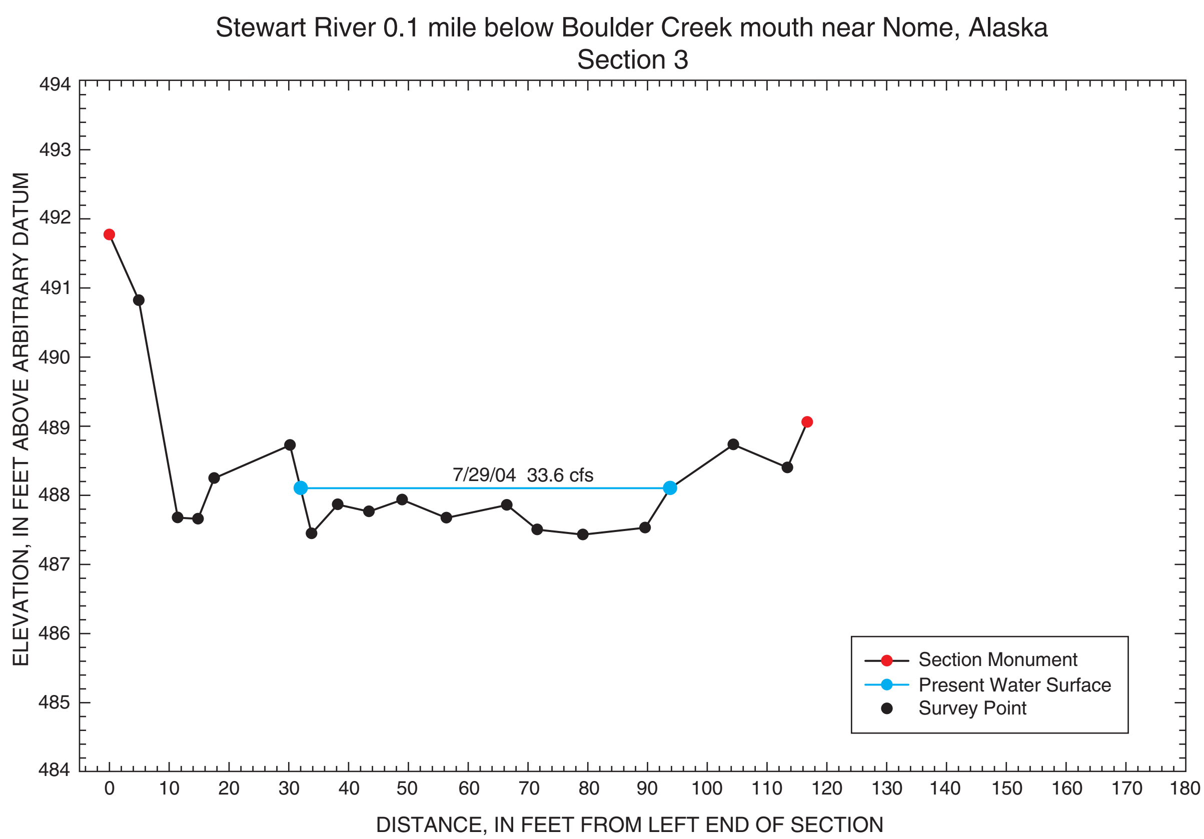
Stewart River 0.1 mi below Boulder Creek mouth near Nome, Alaska (15625850)								Stewart River 0.2 mi below Durrante Creek mouth near Nome, Alaska (15625900)							
Transect	Distance from LEW (ft)	Depth (ft)	Velocity (ft/s)	Thalweg	Bank Vegetation cover (percent)	Bank Erosion	Discharge (ft^3/s)	Transect	Distance from LEW (ft)	Depth (ft)	Velocity (ft/s)	Thalweg	Bank Vegetation cover (percent)	Bank Erosion	Discharge (ft^3/s)
1	LEW				100	N		1	LEW				100	N	
	6.7	2.94	0.519	Y					7	1.3	1.27	Y			
	10.6	1.98	1.02	N					57	0.6	1.33	N			
	18.5	0.68	1.29	N					130	1.2	0.13	N			
	REW				100	N			REW				100	N	
2	LEW				100	N		2	LEW				100	N	
	5.4	0.42	1.78	N					8	1.2	0.98	N			
	8.6	0.48	2.64	N					42	1	1.12	N			
	22.8	0.8	3.85	Y					72	0.9	1.17	Y			
	REW				100	N			REW				100	N	
3	LEW				100	N		3	LEW				100	N	
	14	0.24	1.64	N					15	1.9	0.87	N			
	33.9	0.6	2.38	Y					42	1.5	0.8	N			
	45.7	0.4	1.46	N					60	0.7	2.22	Y			
	REW				100	N			REW				100	N	
4	LEW				100	N		4	LEW				100	N	
	9.5	0.48	0.666	N					16	3	0.49	N			
	20	1.1	1.12	N					40	1.4	0.84	Y			
	28.8	1.58	1.24	Y					65	0.6	0.43	N			
	REW				70	Y			REW				100	N	
5	LEW				100	N		5	LEW				80	N	
	8.8	0.36	1.34	N					14	2.5	0.75	N			88.4
	17.4	0.58	0.648	N					36	1.6	0.94	Y			
	24.5	2.2	1.71	Y					60	0.8	0.44	N			
	REW				80	Y			REW				100	N	
6	LEW				100	N		6	LEW				90	N	
	5	0.42	1.52	N					16	1.9	0.75	N			
	14.3	0.92	1.46	Y					32	2.3	0.84	Y			
	37.3	0.7	1.52	N					55	0.6	0.47	N			
	REW				100	N			REW				100	N	
7	LEW				100	N		7	LEW				100	N	
	8.2	0.8	1.02	N			33.6		9	3	0.25	N			
	19.6	1.2	1.12	Y					30	2	0.46	N			
	32	0.8	0.805	N					53	0.8	0.53	Y			
	REW				90	Y			REW				100	N	
8	LEW				100	N		8	LEW				90	N	
	6.3	1.12	0.412	N					10	2.4	0.68	N			
	13.4	0.9	1.19	N					24	3.4	0.75	Y			
	20.9	1.44	1.12	Y					45	1.1	0.54	N			
	REW				100	Y			REW				100	N	
9	LEW				100	N		9	LEW				80	N	
	3.7	0.88	0.333	N					9	1.5	0.57	N			
	11.5	3	1.67	Y					22	3	0.92	Y			
	21.7	2.84	0.412	N					45	1.3	0.38	N			
	REW				100	Y			REW				100	N	
10	LEW				100	N		10	LEW				100	N	
	8.6	0.48	1.36	N					15	2.4	0.82	Y			
	14	0.86	2.52	N					30	2	0.79	N			
	17.4	1.14	3.48	Y					53	0.9	0.4	N			
	REW				100	N			REW				100	N	
11	LEW				100	N		11	LEW				100	N	
	7.7	0.46	1.86	N					13	0.7	0.16	N			
	15.4	0.86	2.52	Y					66	1.7	0.79	N			
	22.1	0.4	2.17	N					94	0.7	1.78	Y			
	REW				100	N			REW				100	N	

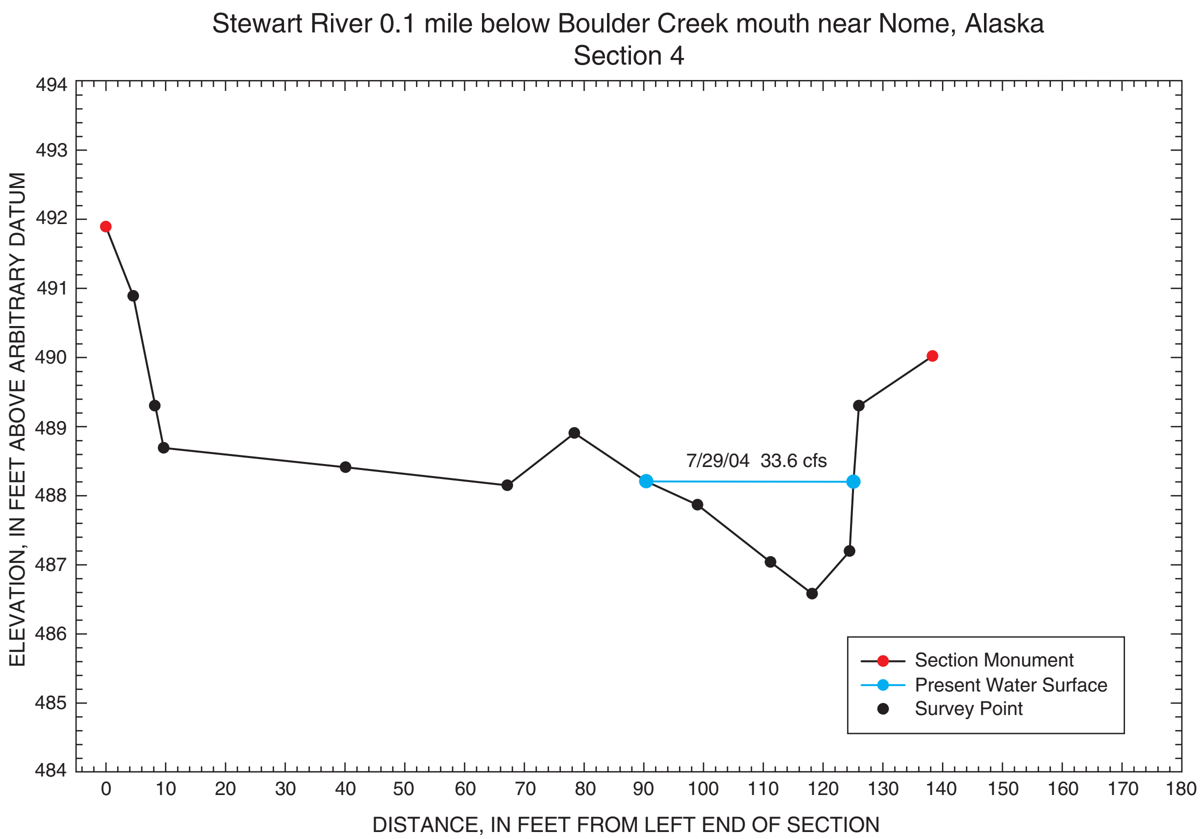
Appendix 3. Graphs showing results of channel surveys along study reaches at the two streamgaging stations on the Stewart River near Nome, July 2004

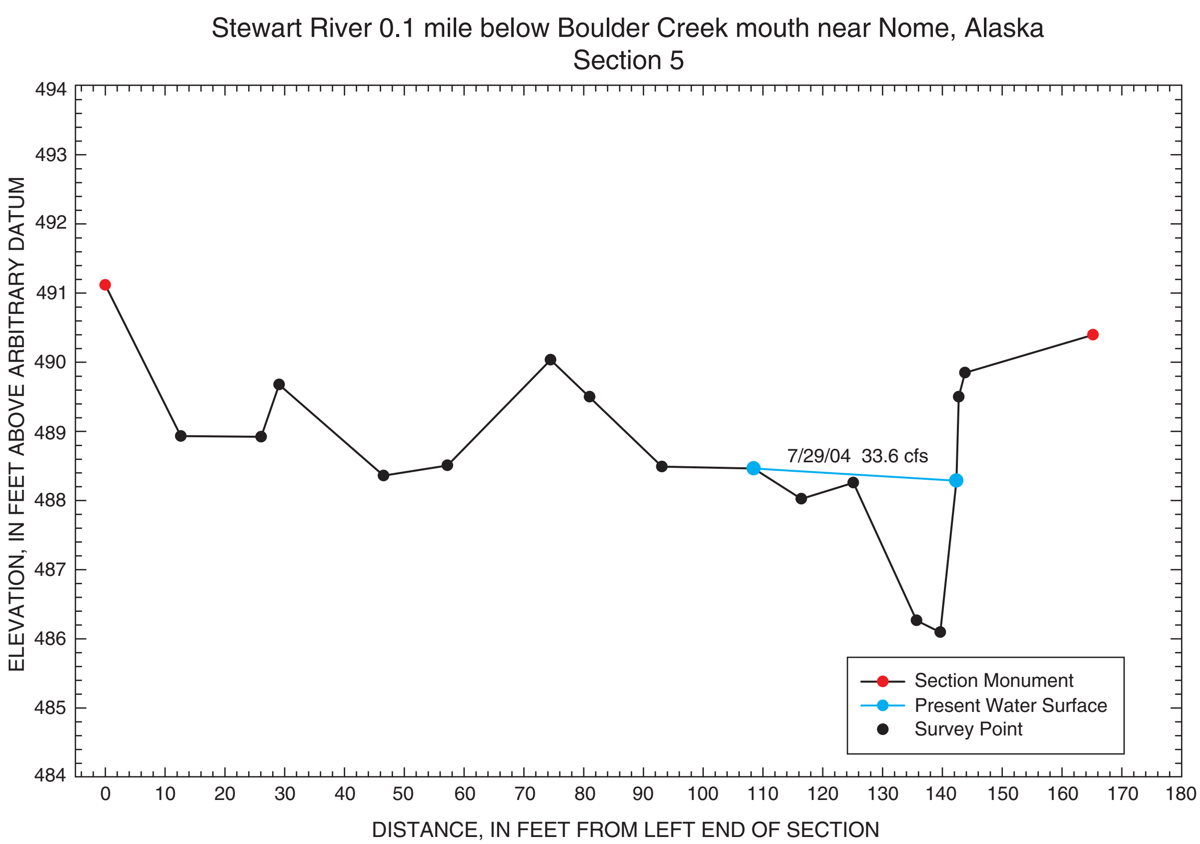





Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 2
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/29/04 33.6 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 3
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/29/04 33.6 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 4
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/29/04 33.6 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 5
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
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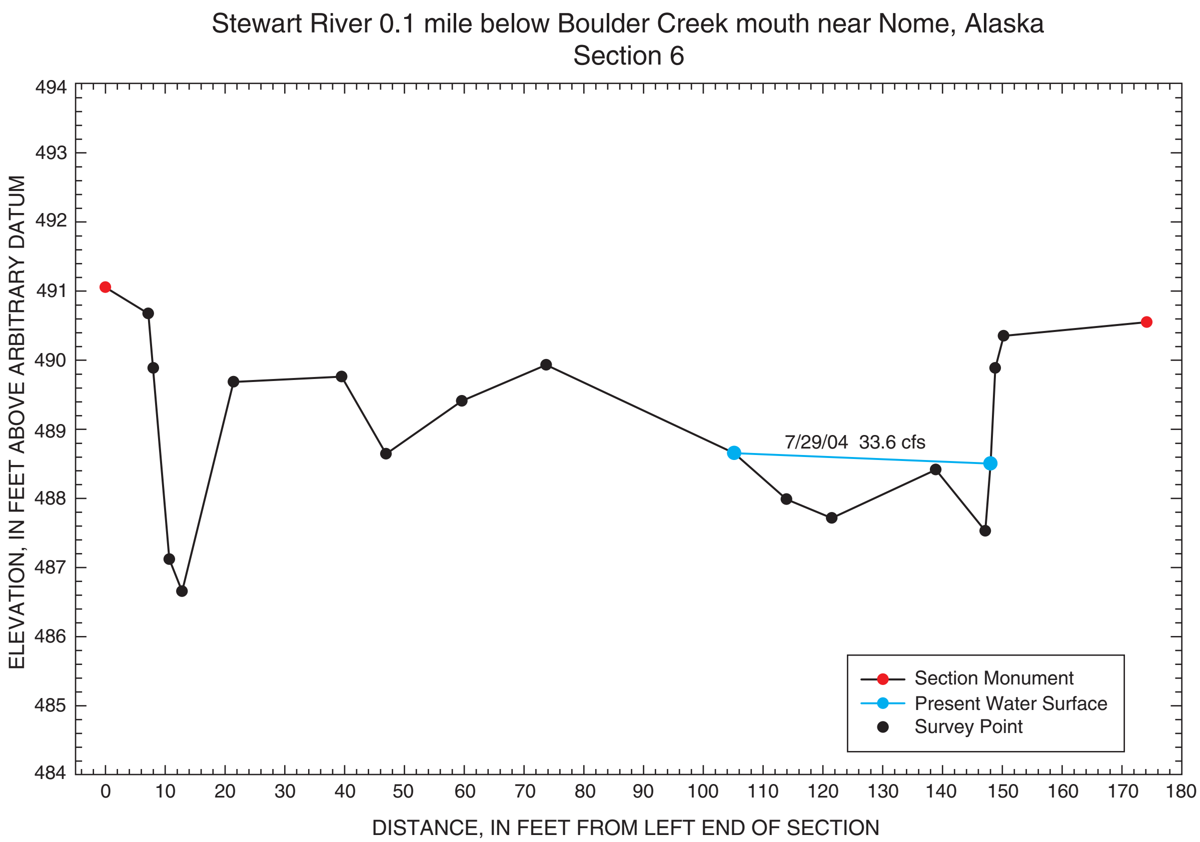
Section Monument
Present Water Surface
Survey Point


Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 6
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
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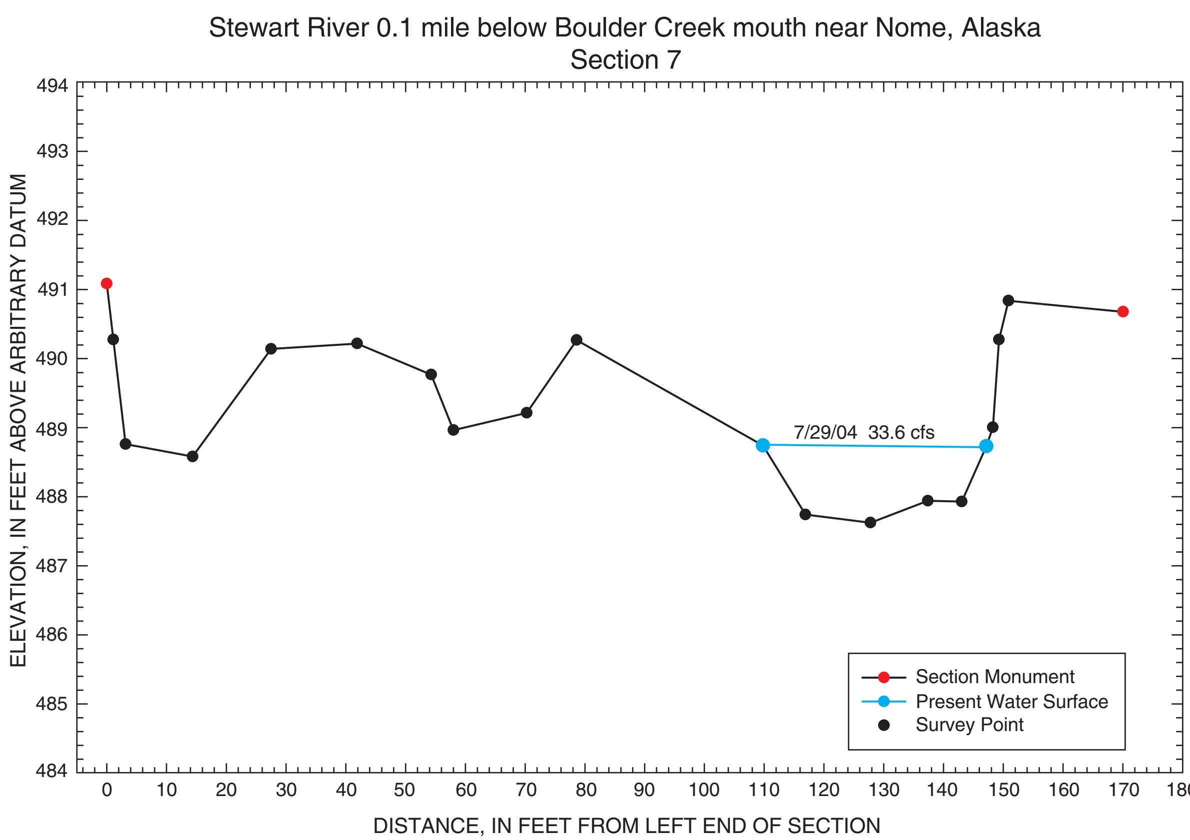
Section Monument
Present Water Surface
Survey Point


Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 7
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
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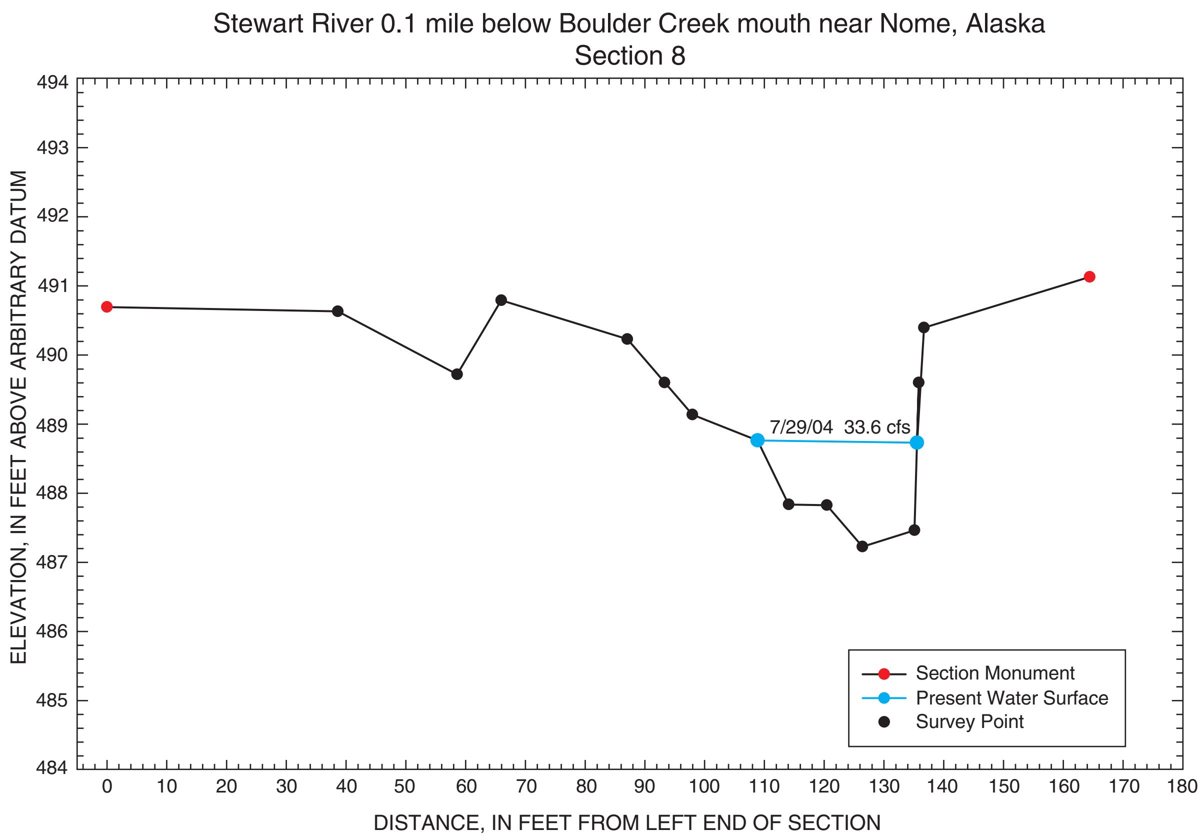
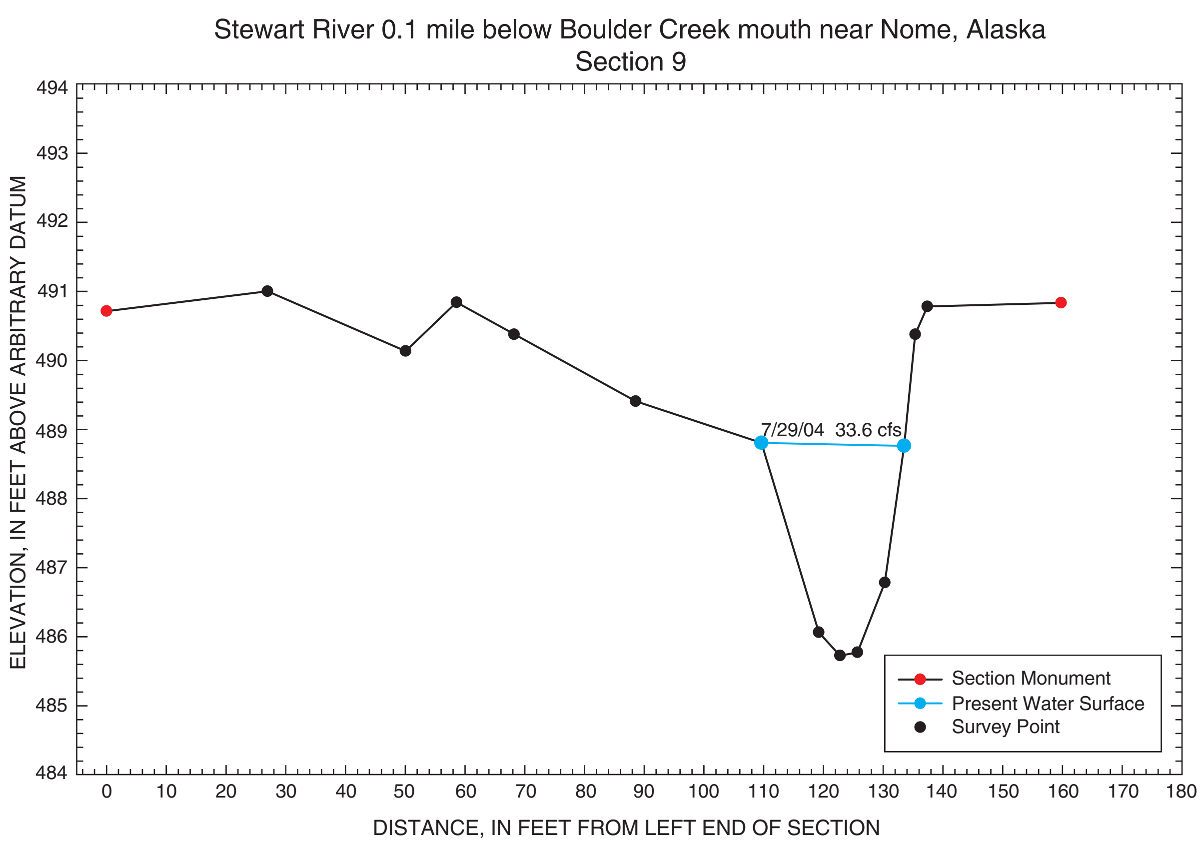
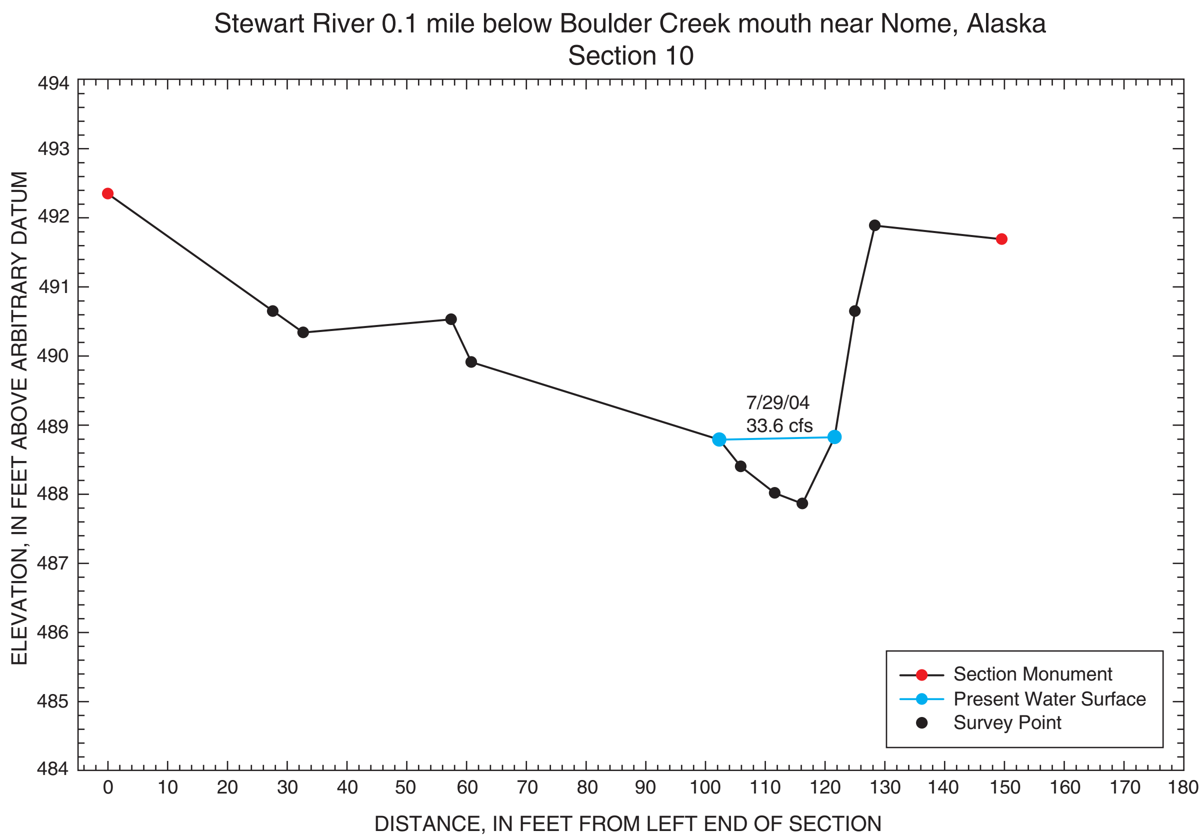
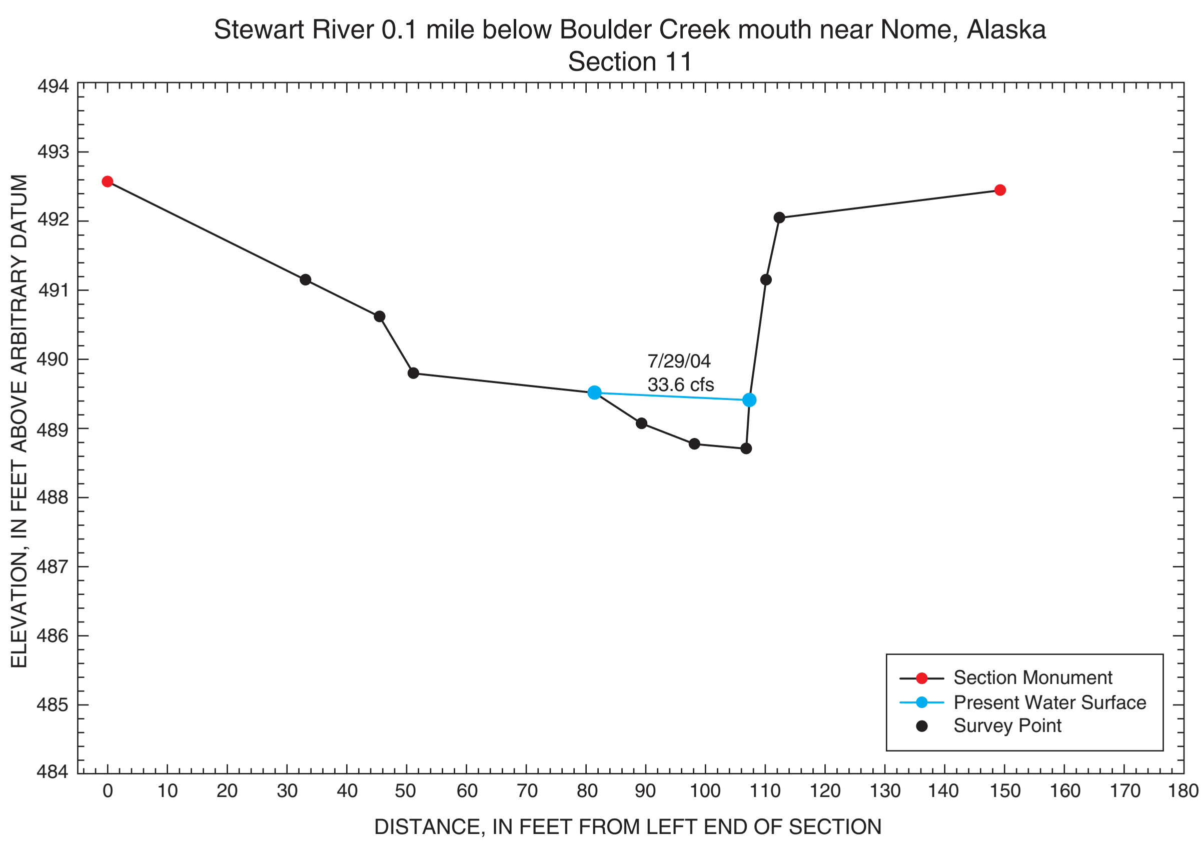
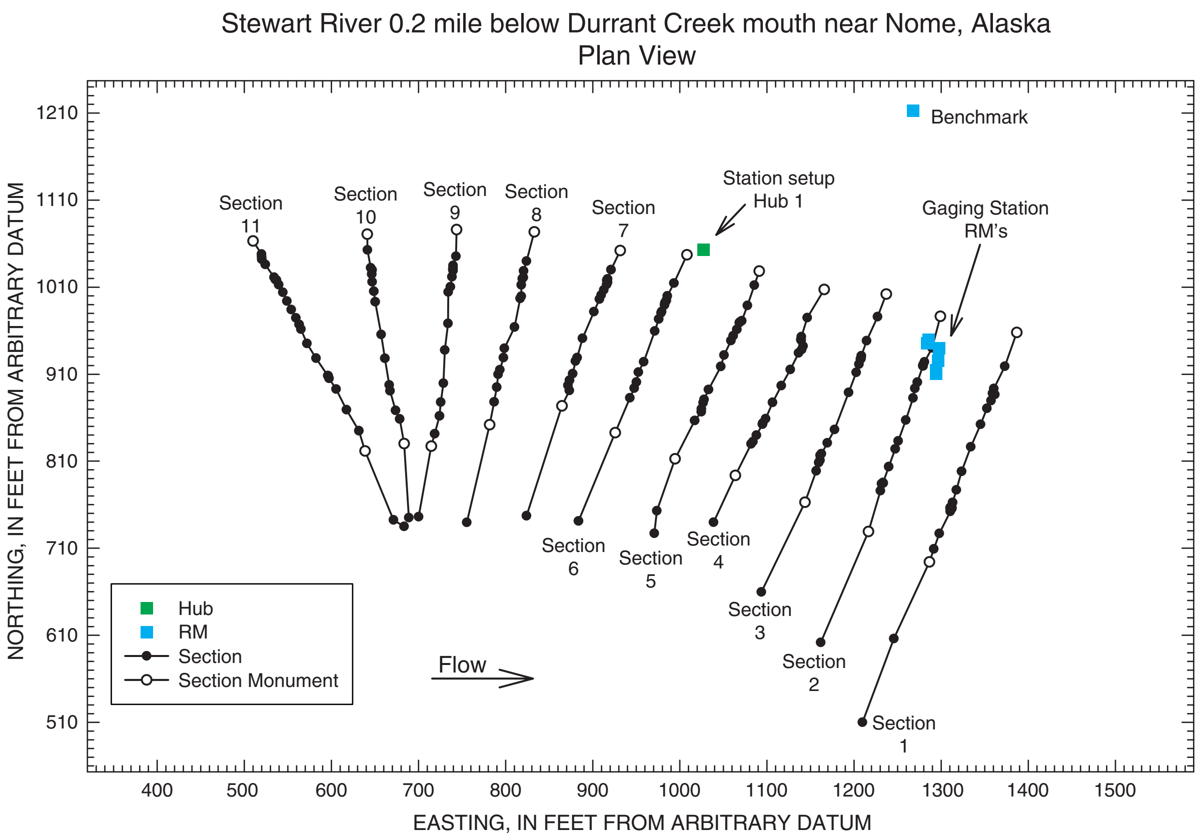
Section Monument
Present Water Surface
Survey Point

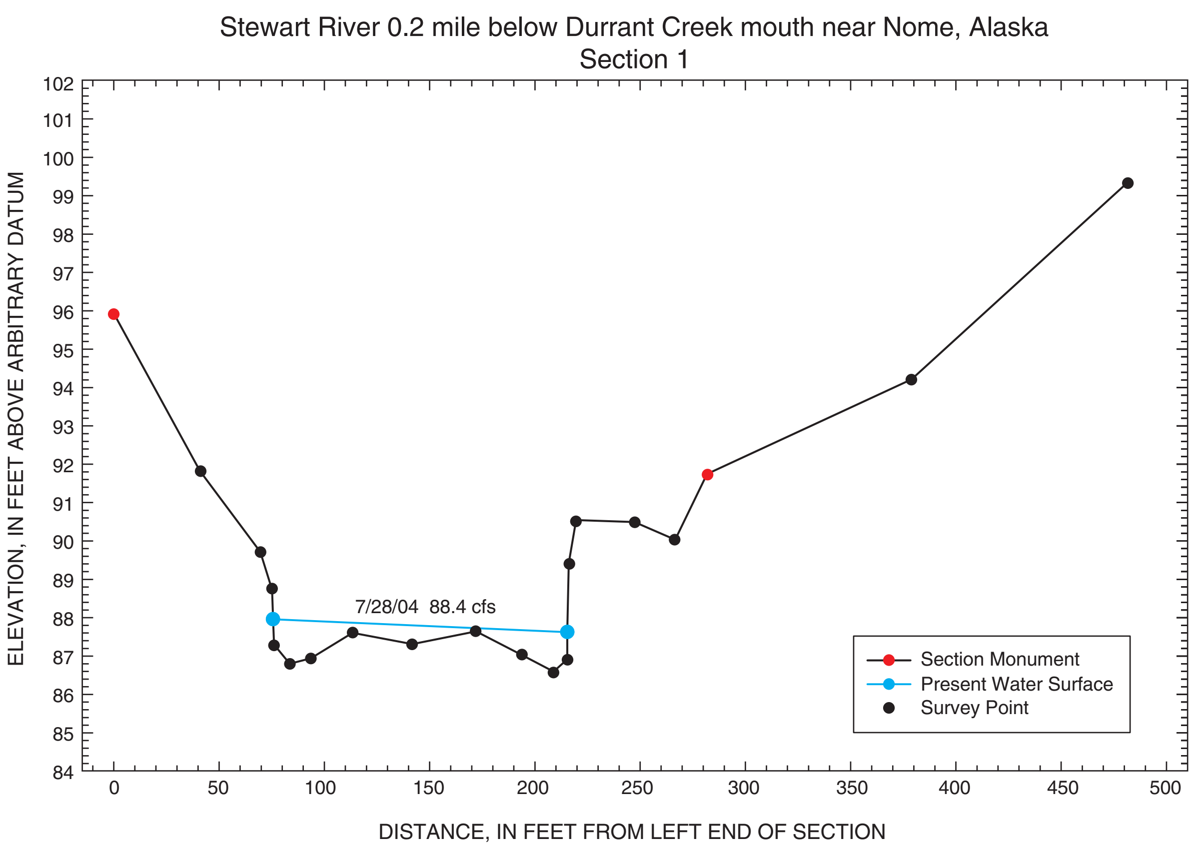

Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 8
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
494
493
492
491
490
489
488
487
486
485
484
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/29/04 33.6 cfs
Section Monument
Present Water Surface
Survey Point

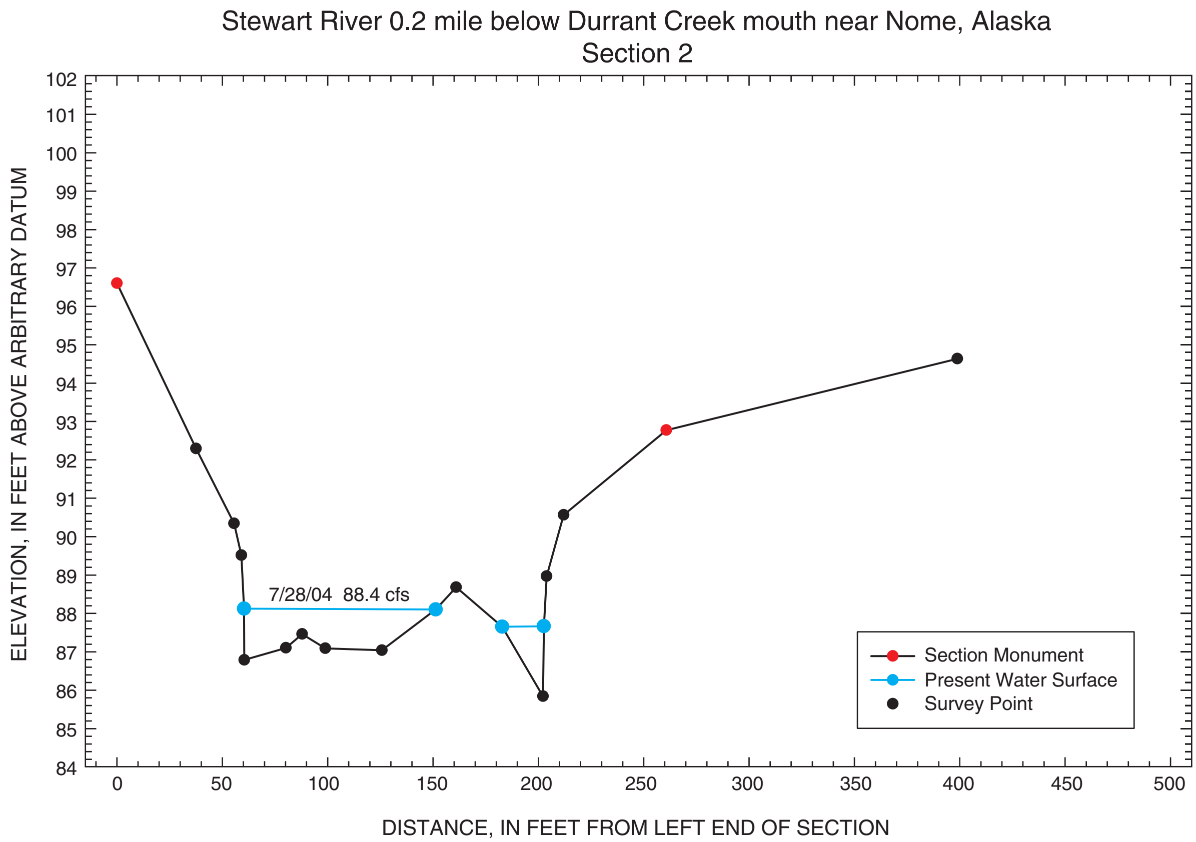

Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 9
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
494
493
492
491
490
489
488
487
486
485
484
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/29/04 33.6 cfs
Section Monument
Present Water Surface
Survey Point

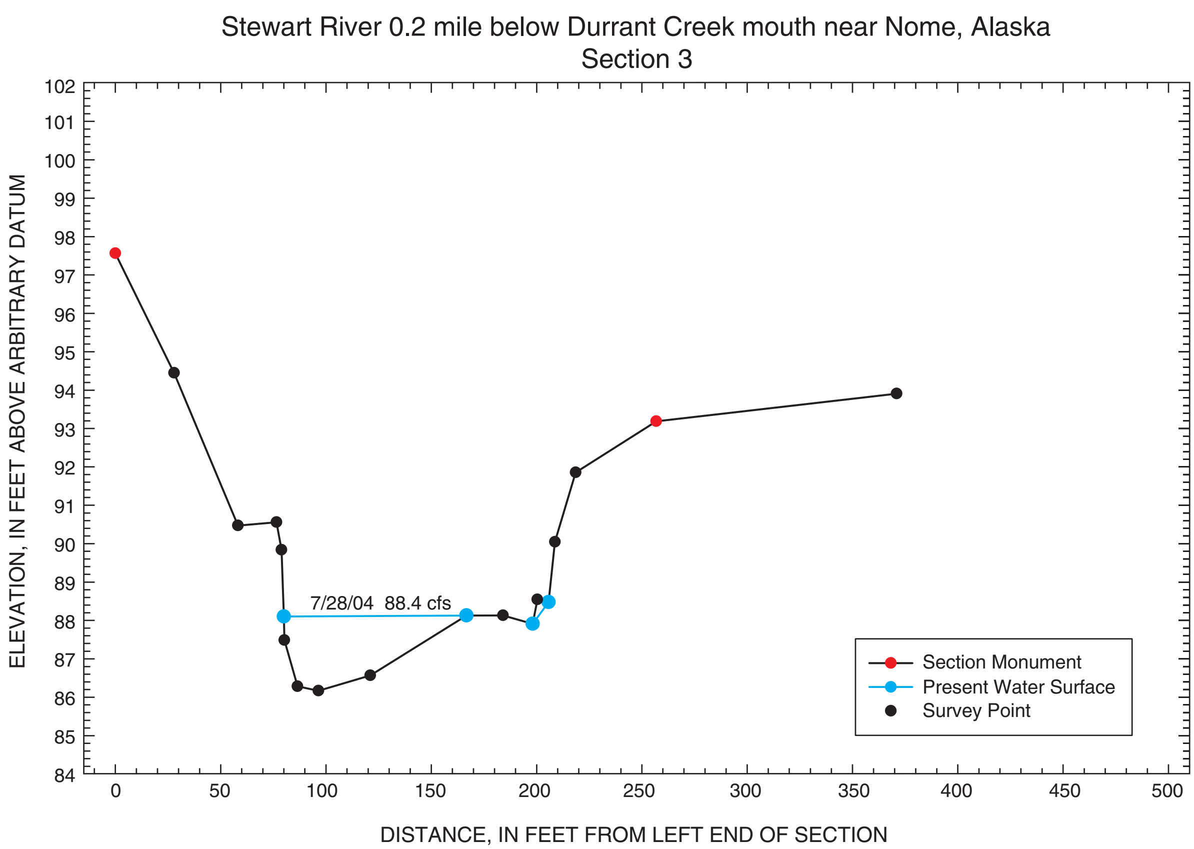

Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 10
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
494
493
492
491
490
489
488
487
486
485
484
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/29/04
33.6 cfs
Section Monument
Present Water Surface
Survey Point

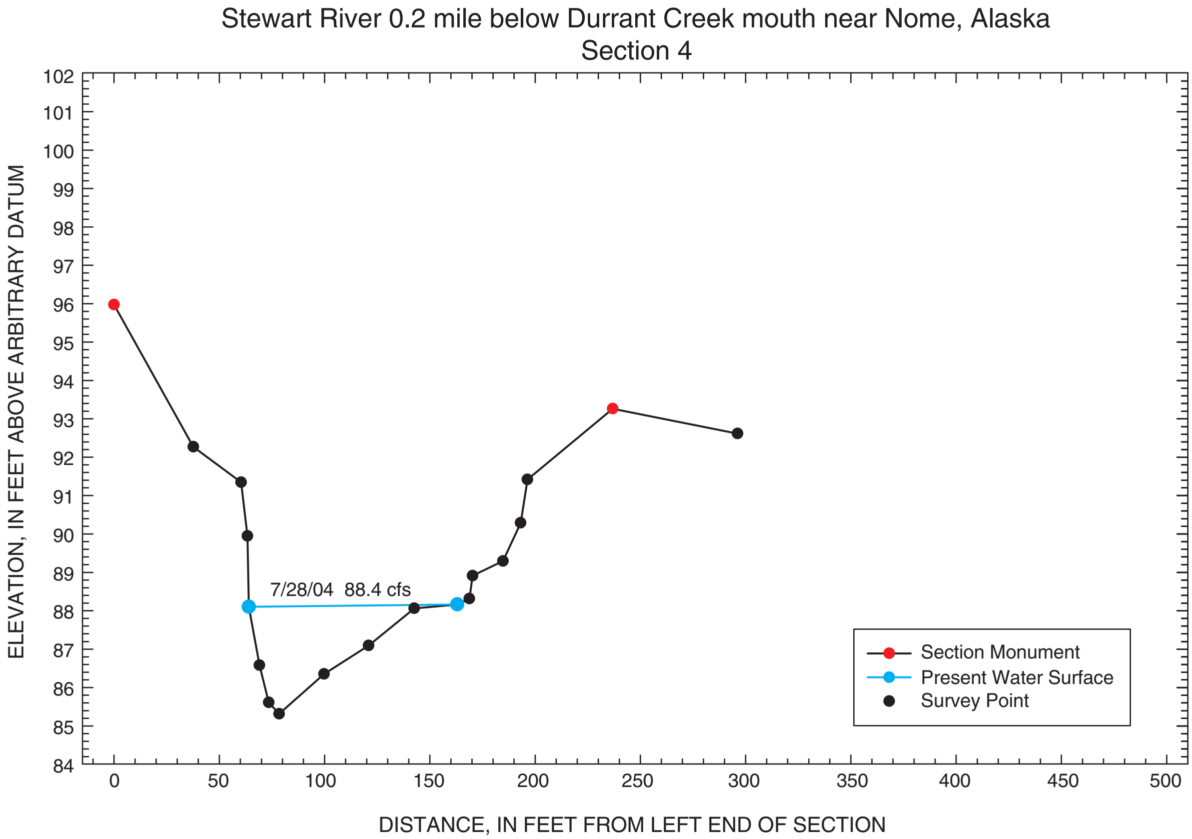

Stewart River 0.1 mile below Boulder Creek mouth near Nome, Alaska
Section 11
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
494
493
492
491
490
489
488
487
486
485
484
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/29/04
33.6 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Plan View
NORTHING, IN FEET FROM ARBITRARY DATUM
EASTING, IN FEET FROM ARBITRARY DATUM
Benchmark
Station setup Hub 1
Gaging Station RM's
Section 11
Section 10
Section 9
Section 8
Section 7
Section 6
Section 5
Section 4
Section 3
Section 2
Section 1
Flow
Hub
RM
Section
Section Monument


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 1
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 2
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 3
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 4
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point
102
101
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
85
84
0
50
100
150
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250
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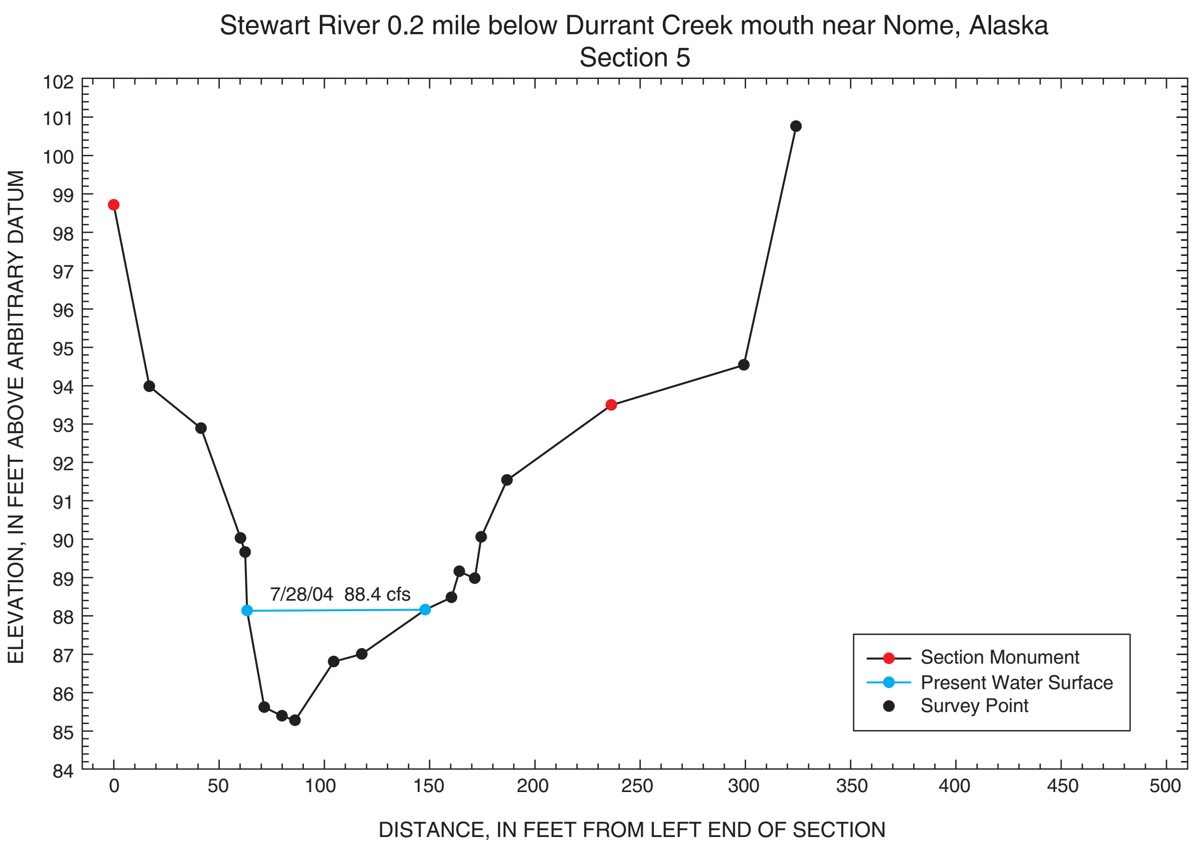
450
500


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 5
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point
102
101
100
99
98
97
96
95
94
93
92
91
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89
88
87
86
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84
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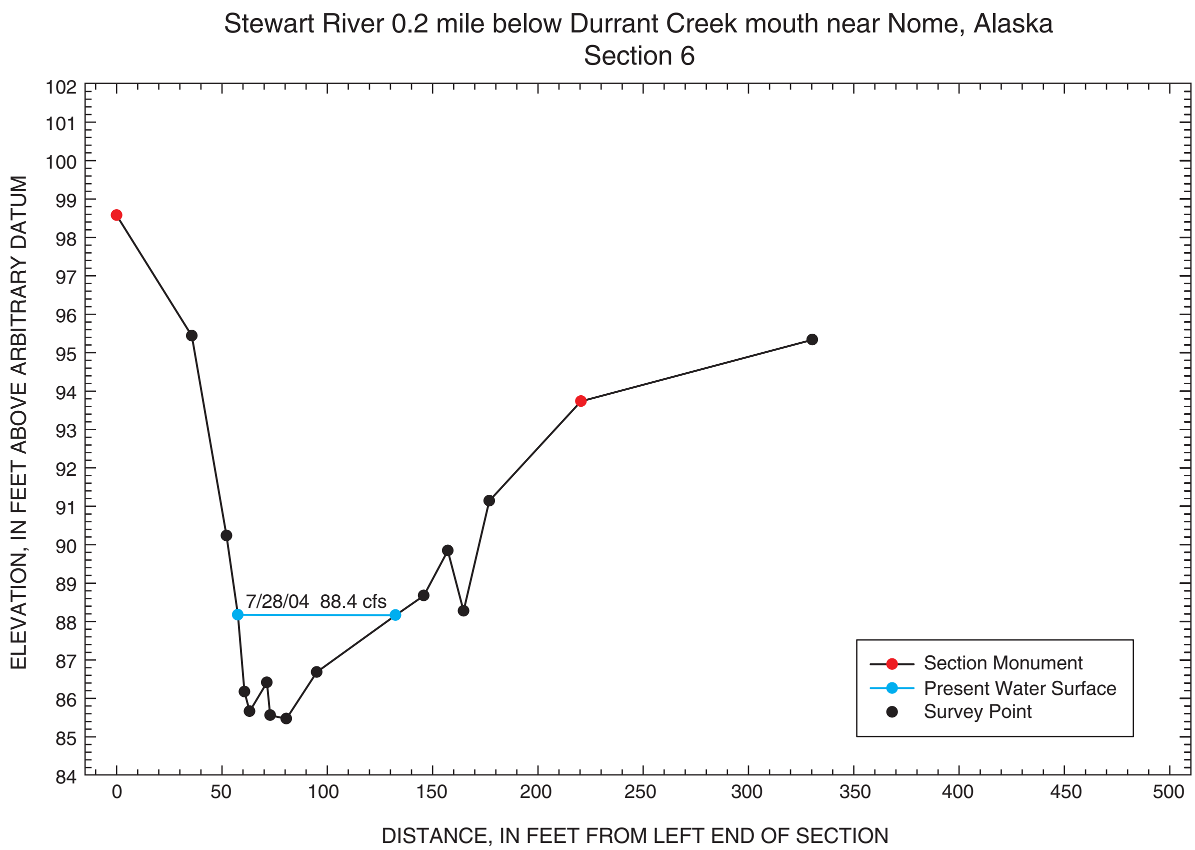
Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 6
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
0
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100
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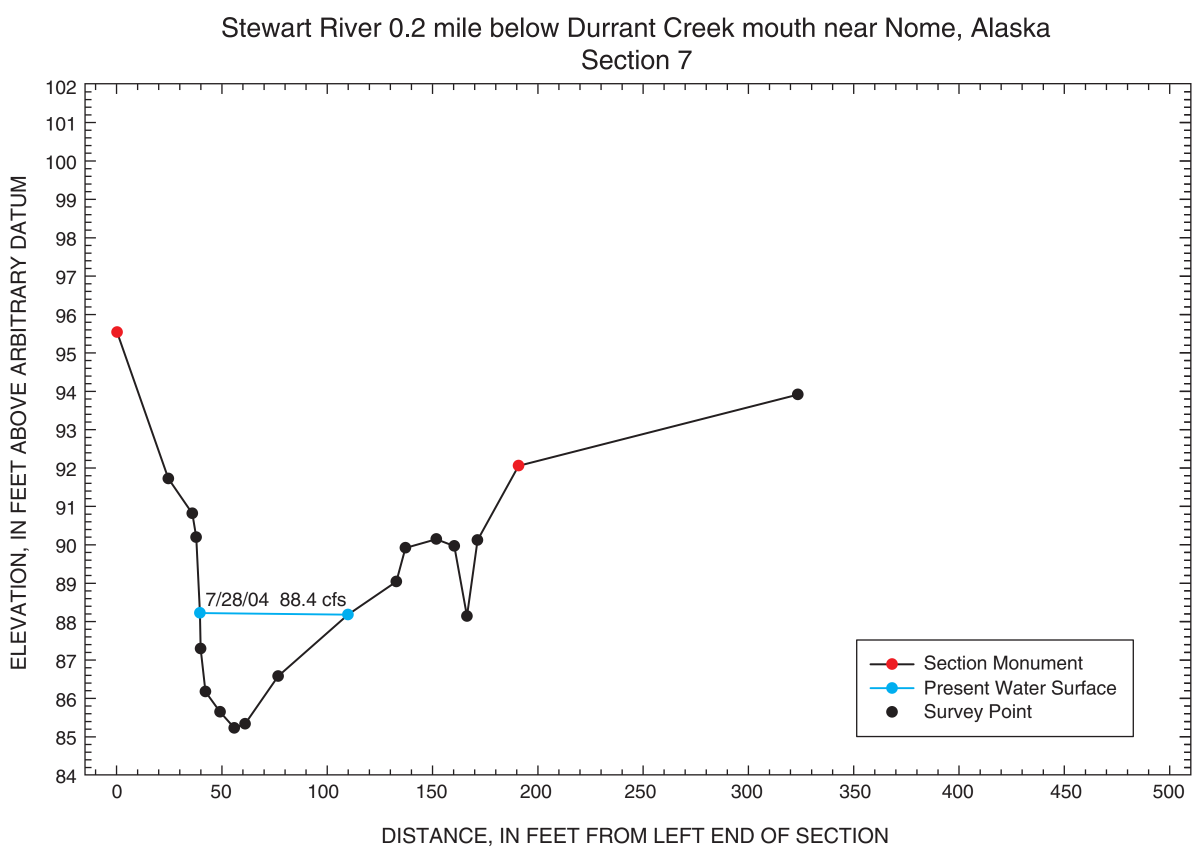
Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 7
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
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100
101
102
0
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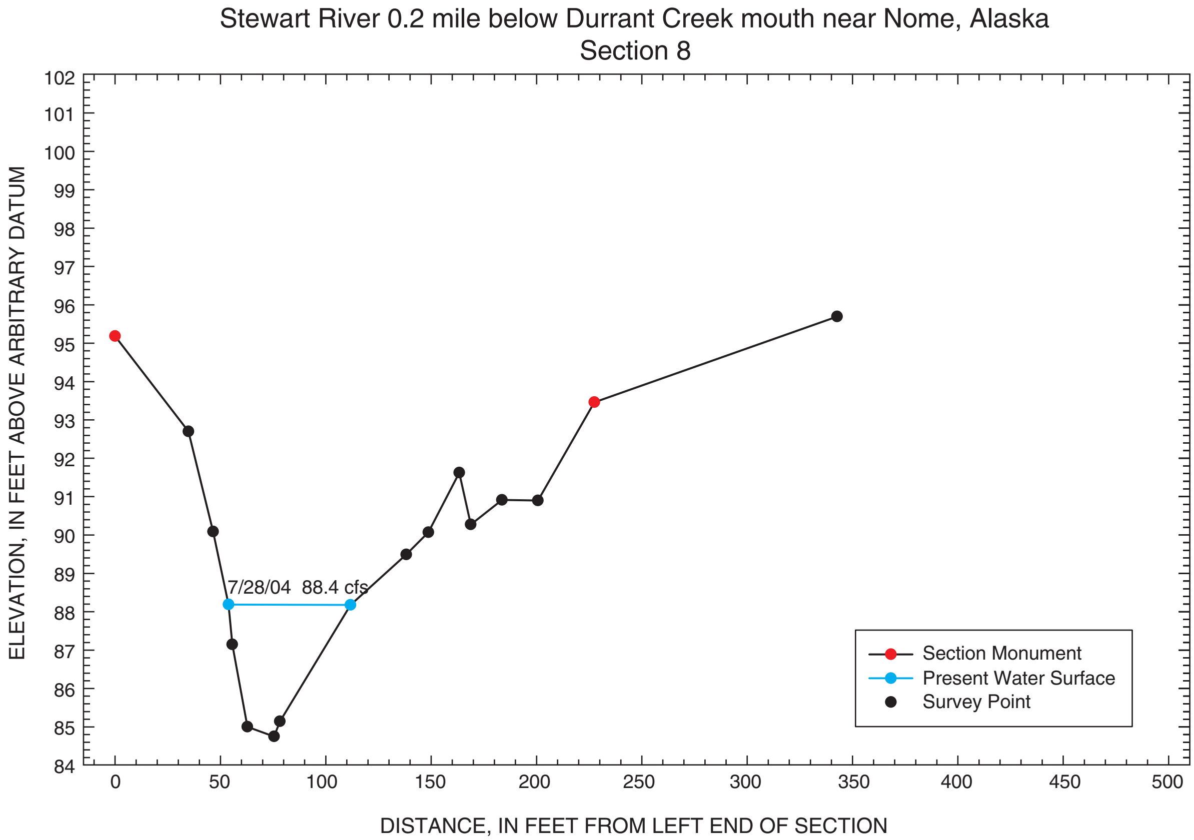
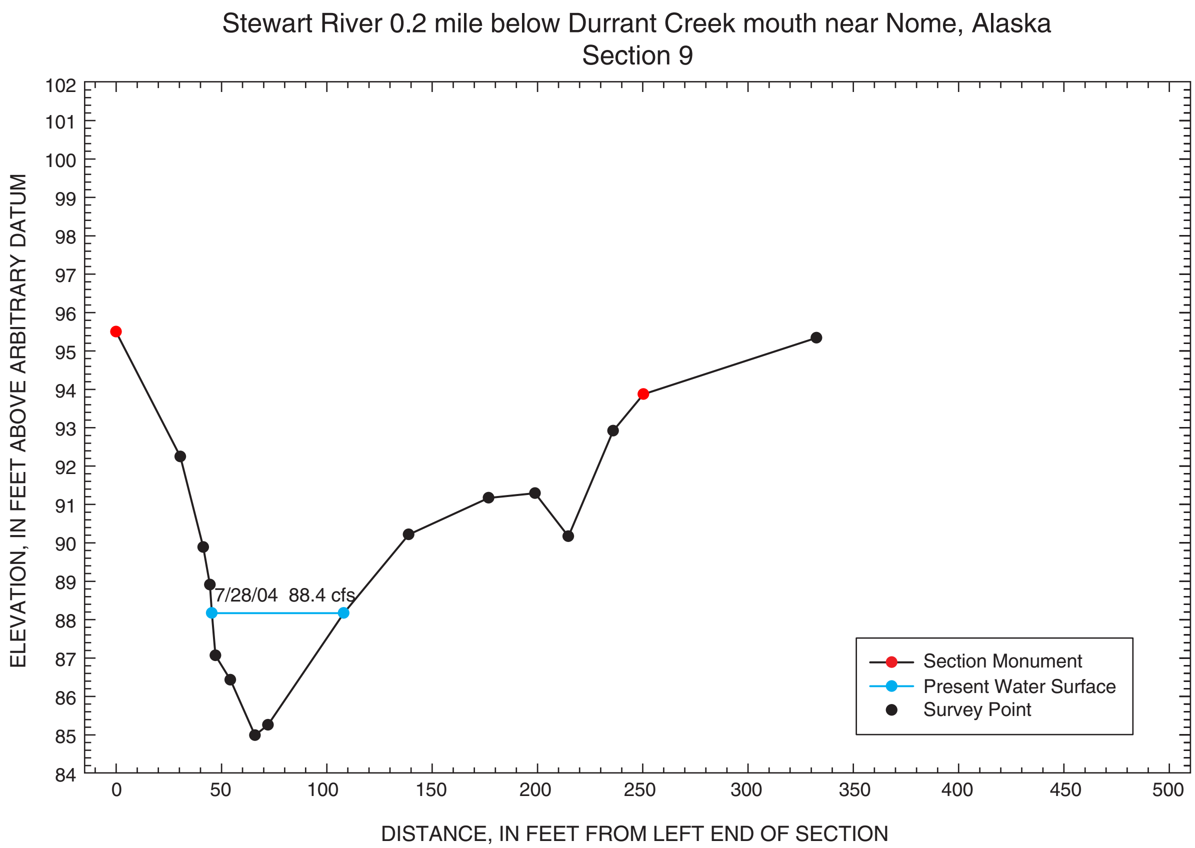
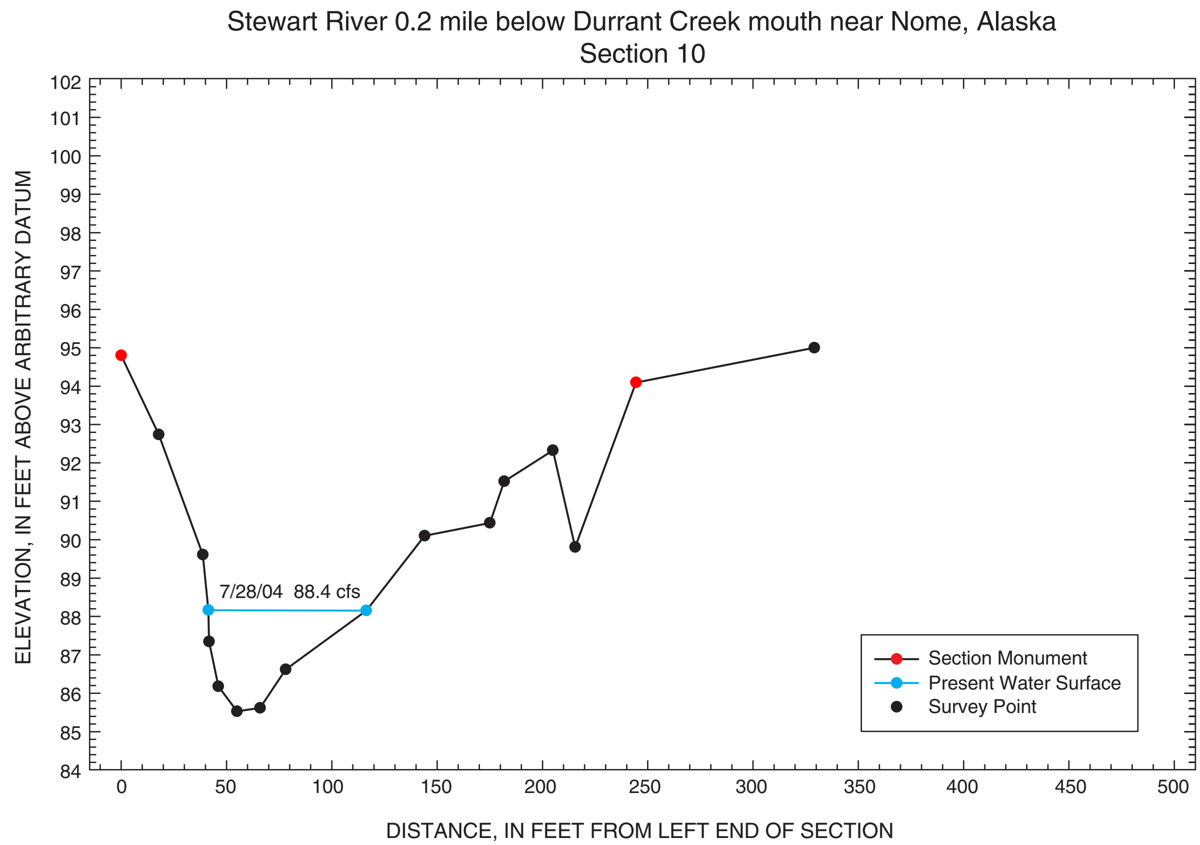
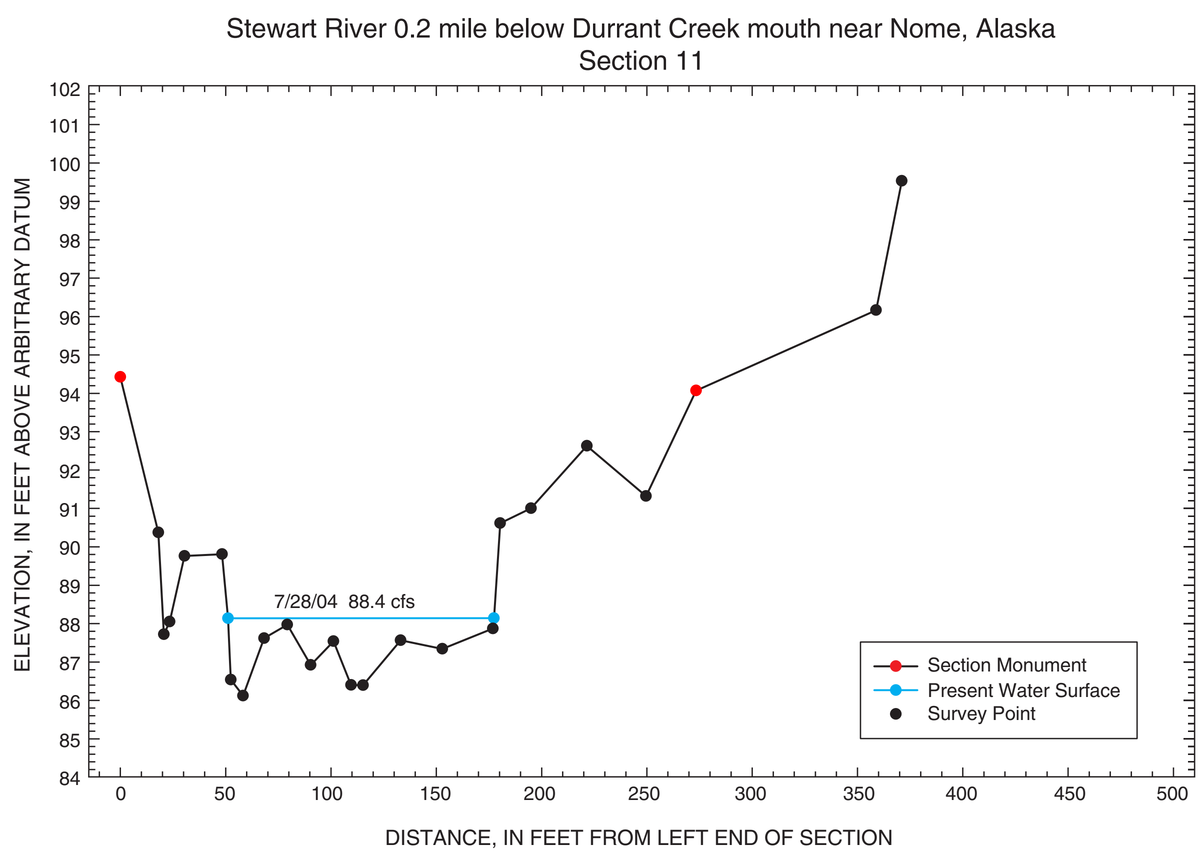

Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 8
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 9
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 10
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point


Stewart River 0.2 mile below Durrant Creek mouth near Nome, Alaska
Section 11
ELEVATION, IN FEET ABOVE ARBITRARY DATUM
DISTANCE, IN FEET FROM LEFT END OF SECTION
7/28/04 88.4 cfs
Section Monument
Present Water Surface
Survey Point