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Hydrologic Investigations to Support Reservations of Water for Lower Talarik Creek, Alaska, 2002–2007

by

Thomas A. Cappiello

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Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 13-04

HYDROLOGIC INVESTIGATIONS TO SUPPORT RESERVATIONS OF WATER FOR LOWER TALARIK CREEK, ALASKA, 2002-2007

By
Thomas A. Cappiello
Alaska Department of Fish and Game, Sport Fish Division, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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Thomas A. Cappiello,
Alaska Department of Fish and Game, Division of Sport Fish,
333 Raspberry Road, Anchorage, Alaska, 99518-1599, USA

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ABSTRACT

Five years of streamflow data were collected on three reaches (A, B, and C) of Lower Talarik Creek to support reservation of water applications for the protection of fish and wildlife habitat, migration and propagation. Reach A was delineated from the mouth of Lower Talarik Creek, where it flows into Lake Iliamna, to the confluence of an unnamed tributary entering from the west ("West Fork") approximately 2.6 km upstream. Reach B continued on the mainstem from the upper boundary of Reach A to the outlet of the first unnamed lake ("East Lake") approximately 11.1 km upstream. Reach C included the West Fork from its confluence at the mainstem upstream to the first unnamed lake (West Lake) approximately 4.2 km upstream. A streamgage was operated on Reach A from July 27, 2002, to September 30, 2007, and a streamgage was operated on Reach C from July 11, 2003, to August 31, 2005. The Reach C gage record was extended to the entire record of Reach A using simple linear regression of the mean daily flows during coinciding gaging periods. Mean daily streamflow for Reach B was estimated using a simple linear regression of same-day discharge measurements made on Reach A and Reach B. Streamflows showed little variation from month to month and from year to year, which is typical of streams with small drainage areas and strong ground water input. Climatological and hydrological information from nearby sites indicated that the five year period of record of this study represented a normal or slightly above normal period of streamflow.

Key words: Lower Talarik Creek, rainbow trout (*Oncorhynchus mykiss*), sockeye salmon *(O. nerka)*, instream flow, reservation of water

INTRODUCTION

Lower Talarik Creek, a tributary to Lake Iliamna in southwest Alaska (Figure 1), is a world-renown angling destination for trophy rainbow trout (*Oncorhynchus mykiss*). The watershed has high fish, wildlife, and aesthetic resource values, and contains known but undeveloped precious metals deposits. The drainage supports a modest run of sockeye salmon *(O. nerka)* but few other salmon. A portion of this area has been designated as the Lower Talarik Creek Special Use Area (ADL 227445) and is to be "managed *(i)* for fish and wildlife populations with emphasis on protecting the rainbow trout fishery and bear population; *(ii)* to provide for traditional subsistence harvest activities; and *(iii)* to accommodate public recreation." The Nature Conservancy (TNC) purchased a 155-acre native allotment parcel adjacent to Lower Talarik Creek to bolster the protection of these values and the long-term health of the watershed. Under a cooperative agreement with the Alaska Department of Natural Resources (DNR) and the Alaska Department of Fish and Game (ADF&G), TNC transferred the parcel back to DNR and was granted a conservation easement on a remaining five-acre parcel.

The goal of this study was to obtain the streamflow data necessary to support a reservation of water for protection of aquatic resources within Lower Talarik Creek, thus complementing the overall land management objectives of the watershed. The Alaska Water Use Act (AS 46.15) and associated regulations provide the opportunity for private individuals and state, federal, and local government agencies to legally acquire a specific type of water right (known as a "reservation of water") to maintain a specific flow rate in rivers, or level of water in lakes, for one or a combination of four types of uses:

- protection of fish and wildlife habitat, migration, and propagation
- recreation and parks purposes
- navigation and transportation purposes
- sanitary and water quality purposes

To obtain a reservation of water, an application must be submitted to DNR. The application must document supporting data and analysis that substantiate the need for, and availability of, the amount of water being requested. An application meeting regulatory requirements is adjudicated (the administrative determination of the validity and amount of a water right, including the settlement of conflicting claims among competing appropriators) and a water rights certificate issued. Ideally, 20 or more years of streamflow data are desired for the statistical characterization of a river's flow regime; however, DNR considers five years of flow data sufficiently reliable for the purpose of quantifying flow or water levels for reservations of water. Modeling or correlations using appropriate longer-term gage records can be used to extend shorter-term flow records to meet this criterion. Record extension techniques are used by U.S. Geological Survey (USGS) and others to improve (reduce error and bias) statistical measures of streamflow at short-term gaging stations. At least two years of concurrent gage data are desirable for extending short-term gage records.

Fish and wildlife need particular flows or water levels for their various life history stages and for the formation and maintenance of their physical habitat. Out-of-stream uses of water can alter the duration (how long certain flows persist), timing (when certain flows occur), and magnitude of seasonal flows, which in turn can impact the distribution, abundance, growth, and survival of fish (Poff and Allan 1995; Acreman and Dunbar 2004; Annear et al. 2004). Likewise, the formation and maintenance of specific habitat features (substrate, woody debris, pools, riffles, etc.) depend on various features of a natural flow regime.

This is the final report of a five-year effort collecting the streamflow data needed to support reservations of water for three reaches within the Lower Talarik Creek watershed.

OBJECTIVES

1. To collect and analyze site-specific hydrological data needed to support reservations of water to protect fish and wildlife habitat in three reaches of Lower Talarik Creek.

   Tasks

   1. Install and maintain two continuous-record stream gaging stations to estimate mean daily flows on two reaches of Lower Talarik Creek. One gage is to operate as an index gage for five years; the other as a temporary gage to operate for two years to correlate with the index gage.

   2. Measure discharge several times per year at a range of flows throughout the year to develop a stage-discharge relationship at the gaged sites.

   3. Establish a discharge measurement station on a third reach to estimate mean daily flow by correlating to flows measured at the index gage.

   4. Estimate mean daily flows and other statistical measures representing five years for all three reaches.

STUDY AREA

Lower Talarik Creek is a relatively small stream with a drainage area of 161 km^2 (Figure 2). The drainage has a number of small lakes dominated by open low scrub tundra with patches of closed willow scrub in the floodplain. Trees are primarily sparse patches of black spruce (*Picea mariana*). The dominant channel substrate ranges from sand to gravel in size. Bank vegetation is mostly grasses (*Calamagrostis spp*.), sedges (*Carex spp*.), willow (*Salix spp*.), and some alder (*Alnus spp*.).

An administrative cabin owned by ADF&G, located adjacent to the southeast shore of a ponded portion of the lower creek known as the “lagoon,” provided a base during site visits. There are several ways to access Lower Talarik Creek. The most common access is by a deHaviland DHC-2 Beaver fixed-wing aircraft on floats chartered from the village of Iliamna and landing either on Lake Iliamna or the lagoon. Wind and waves on Lake Iliamna often prevent landing, while the lagoon has a rather short take-off distance and can be too shallow for planes on floats during low-flow periods. Another means of access is by a small wheel plane to a sandy stretch along the Lake Iliamna shoreline, near the ADF&G cabin. During winter, access is primarily by fixed-wing aircraft on skis or wheels to Lake Iliamna when lake conditions allow. Only once during this project was a helicopter needed; fortunately, one was available in Iliamna under a contract for exploration associated with the Pebble Copper/Gold Prospect.

METHODS

REACH IDENTIFICATION

A reservation of water application needs to be made for a particular stream reach (or point). The streamflow data collected at a selected site is assumed applicable to the entire reach. Therefore, streams are typically segmented into reaches, such that the streamflow is not substantially different (plus or minus approximately 10%) between the upstream and downstream boundaries. In cases when the data for a portion of a stream are unavailable or too costly to acquire, the downstream reach boundary is set further downstream than normal, with the understanding that the hydrological data at the collection point may be biased low for some of the reach. This practice is something of a trade-off for acquiring instream flow protection on a greater portion of the waterbody.

Initially, three reaches on Lower Talarik Creek were identified based on the hydrography represented on USGS 1:63,360-scale topographic maps (Figure 2). Reach A was established from the mouth of Lower Talarik Creek, where it flows into Lake Iliamna, to the confluence of a major unnamed tributary entering from the west (referred to as West Fork), approximately 2.6 km upstream. Reach B was established from the upper boundary of Reach A to the outlet of the first unnamed lake (referred to as “East Lake”), approximately 11.1 km upstream. Reach C was established as the West Fork from its confluence at the mainstem upstream to the first unnamed lake (West Lake), approximately 4.2 km upstream. During a reconnaissance trip in August of 2000, several discharge measurements were made at key geographical points within the drainage to help finalize these reaches.

Reach A had the best access for an index gage, but ideal gage sites were limited. A section of stream just below the confluence with the West Fork was chosen because it had little chance of backwater occurring and was unlikely to interfere with anglers targeting trophy rainbow trout. The Reach A gage was established in a channel-controlled section, with gravel and sandy substrate and a fairly even bottom topography.

Upstream from the Reach A gage site, additional sites for gages were extremely limited. Reach B was low gradient and candidate gage sites were subject to backwater from Reach C. It also had a silty and sandy substrate that posed an unstable channel control. Reach C had multiple channels, low-lying banks, and boggy riparian areas. Therefore, the outlet of the unnamed lake on the West Fork was selected for a temporary gage to quantify streamflows for Reach C. With the assumption that some accretion would occur between reach boundaries, this was an adequate approach for determining water quantity and availability throughout the reach. The outlet of the East Lake was another possible gage site, but access either by float or wheel plane was deemed too unreliable and dangerous for regular site visits.

USGS assigns a unique identification number to data collection stations, whether stream site, lake, reservoir, spring, or well. This number is unique, applying specifically to a given station and to no other. Once this number is assigned, it is usually retained for that station indefinitely. The numbering system, however, does not distinguish whether the station has a gage (continuous records) or is limited to only partial records. Following the USGS example, station identification numbers were assigned to each ADF&G station where data were collected, as follows:

Station Name (type)	Station number	Latitude	Longitude
Reach A (gage)	10201	59.6304	-155.53396
Reach B (discharge only)	10204	59.6307	-155.53247
Reach C (gage)	10203	59.6592	-155.56256
East Lake (discharge only)	10202	59.6776	-155.47636

Coordinates based on NAD83

GAGING

Gaging methods followed USGS procedures described in Rantz and others (1982). The Reach A and C gages consisted of two vented Druck©[1] PDCR 1830 (5 psig) pressure sensors, each housed in a perforated well point driven diagonally through a slightly undercut bank into to the stream substrate. Each pressure sensor cable was threaded through a flexible metal conduit and connected to a Campbell Scientific Instruments CR10X data logger housed in a weatherproof box. A temperature probe and cable were threaded through the conduit with one of pressure sensors. The data logger was programmed to activate sensors and record the water stage at 15-minute intervals, and to record water and ambient (inside the datalogger) temperatures at four-hour intervals.

Three elevation reference marks (RM) were installed near each gage to establish a gage datum to convert recorded water depth to water surface elevation (WSE) relative to this datum. An arbitrary elevation of 100 ft was assigned to the primary RM. The WSE and other RM elevations in relation to the primary RM were determined by differential leveling at the time of the gage installation (Kennedy 1990). Instead of installing and relying upon a reference staff gage, differential leveling was performed during each site visit.

DISCHARGE MEASUREMENTS

Discharge was measured following the USGS midsection method (Rantz and others 1982), using either a Price AA or Pygmy (depending on stream depth and velocity) vertical axis velocity meter on a top-setting wading rod. Discharge is defined as the volume rate of flow of water and is reported in cubic feet per second (cfs) rather than in metric terms as a universal convenience.

[1] Product names used in this publication are included for completeness but do not constitute product endorsement.

Discharge is determined by measuring the average velocity, depth, and width of sub sections across the discharge measurement transect. Ideally, each subsection should represent no more than 5% of the total flow. A JBS Energy, Inc., AquaCalc® electronic digital counter was used to record the depths, count meter revolutions, and calculate discharge. These data and calculations were also recorded on standard USGS field forms or in similar format in rite-in-rain notebooks as a backup. All instruments were maintained, calibrated, and operated according to their respective manufacturer's instructions and USGS manuals and technical memos (Rantz and others 1982). For discharge measurements under ice cover conditions, a gas-powered ice auger was used to drill holes along a transect. A USGS-approved ice meter and rod was used to measure mean water column velocity; depth was measured from the bottom of ice in the water to the substrate; and discharge was calculated as above and multiplied by a standard ice roughness factor of 0.92 (Nolan and Jacobson 2000).

SITE VISITS

Site visits were made two to four times a year to download data, measure discharge, and perform routine maintenance. The intent was to measure discharge over a range of flows and throughout the year to determine the stage-discharge relationship. During each site visit, discharge was measured at the gages in Reaches A and C, and in Reach B. Occasional site visits were made to measure discharge at the outlet of the East Lake, the upstream boundary of Reach B. On occasions when icing and overflow conditions prevented an effective discharge measurement at the Reach A gage, suitable sites downstream from the usual discharge transect were used instead.

DATA ANALYSIS

Gage Records

Data collected at each gage were entered into Kisters WISKI© hydrological software for storage, management, and analyses. WISKI© uses USGS standards and techniques for data reduction and computations. WISKI© was also used to develop a rating curve, analyze, and correct stage data for errors or missing data, and to calculate mean daily flows based on recorded stage values.

Prior to uploading, the 15-min stage data were evaluated in tabular and graphic formats to identify data gaps and anomalies. If less than 50% of a daily 15-min stage record was missing or anomalous, data points were corrected or inserted using linear interpolation between the accepted data points. If more than 50% of a daily 15-min stage record was missing, the mean daily flow was estimated by linear interpolation between the calculated mean daily flow records.

During winter, hydraulic head pressure is often altered by ice cover, making gage pressure readings invalid and precluding the use of a stage-discharge relationship for calculating streamflow. For periods of ice cover, stage data were not used and mean daily flow records were estimated based on winter discharge measurements and from temperature or flow trends from nearby USGS gages at Koktuli (Station 15302200) and Upper Talarik Creek (Station 15300250), following Melcher and Walker (1992).

Pressure sensors have a tendency to drift or provide slightly biased readings over time due to a variety of circumstances, such as algae growth or siltation. These readings are corrected using a reference gage, such as a staff gage, or a level survey of the water surface elevation based on a permanent elevation benchmark. Benchmark elevations can also change—from frost jacking or isostatic rebound, for example—but such occurrences are uncommon and extremely difficult to assess. For this study, the 15-min stage record was "corrected" accordingly using the differential level survey results.

Once the stage record, discharge measurements, and surveyed WSE data were checked for errors and uploaded, a rating curve was developed for each gage to convert the stage records to discharge values. WISKI© has a graphical interface that allows the user to develop a rating curve following the USGS approach, which uses a linear regression of the log-transformed discharge measurements and WSE readings (Rantz and others 1982; Kennedy 1983). The rating curve was modified or "shifted" following any significant changes to the hydraulic control (from scour or deposition), according to (Rantz and others 1982). Analysis and calculation of mean daily flow from the Reach C gage data was contracted out to Water Walkers Streamflow Monitoring, Inc.

Mean Daily Flow and Statistical Procedures

The rating curve was applied to corrected 15-minute stage values to determine the 15-minute flow values. Mean daily flows were computed by taking the mean of 15-minute flow values for each day in the period of record. If there were fewer than 50% of the daily 15-min stage values in the record, the mean daily flow was estimated by linear interpolation between records from the day prior and the following day. Values of daily mean flows in this report follow USGS standards and are shown to the nearest tenths between 1.0 and 10 cfs and to whole numbers between 10 and 1,000 cfs. The same rounding rules apply to measured and extended discharge values.

Mean daily flows computed for each gage record were transferred into tab-delimited data files. The data were analyzed by a series of Statistical Analysis System® programs using the procedures outlined below to estimate mean of mean daily flows across years (calendar day mean), mean annual flow, mean monthly flow, and monthly flow duration values.

Mean annual flow was estimated as a mean of the annual mean daily flow values over all complete water years of record. Mean monthly flows were estimated as the mean of monthly mean daily flows for all complete months over the entire period of record. Duration estimates represent the expected frequency of occurrence of mean daily flows within the specified time periods. The durations of daily mean flows were calculated as the percentiles of the empirical distribution of observed values within the specified time periods over the period of record. This provided an estimate of the percentage of time a given mean daily flow was equaled or exceeded within the distribution of mean daily flows for each time period analyzed.

Extension of Flow Records

DNR has a policy requiring a minimum five years of continuous mean daily flow data to support a reservation of water application. When less than five years of continuous flow data are available for a candidate stream, extension of existing shorter-term flow records from a nearby and longer-term gage record can be an option. Extension methods seek to balance the data required to obtain minimally biased flow statistics with resource constraints and the Department's need to be efficient and effective in securing reservations of water. The intent was to minimize the potential for bias while recognizing the reality of resource limitations, the legal standards pertaining to the acquisition of water, and departmental mandates and objectives.

A simple linear regression was used to determine the relationship between the concurrent discharge measurements in Reach B and those at the Reach A gage. The regression equation was applied to the computed mean daily flow records for Reach A to develop a mean daily flow record for Reach B. Statistical analysis using Statistical Analysis System as described above was applied to the mean daily flows for estimated for Reach B. The original reservation application for Reach A was based on a regional equation developed by USGS (Parks and Madison 1985) rather than site-specific empirical data; therefore, an amended data analysis had to be submitted within a five-year deadline.[2] The gage record did not begin until 2002, so about two years of data were available by this deadline (August 1, 2002, through September 30, 2004). When gaging in Reach A was completed in September 2007, the regression was updated to include additional measurements that took place after the reservation amendment was filed. This additional data analysis will be needed to support the reservation flow quantities during adjudication of the reservations of water that were filed for these reaches.

A simple linear regression was used to quantify the relationship between mean daily flows calculated from the Reach C gage (July 1, 2003, through August 31, 2005) and the coinciding record of mean daily flows from the Reach A gage. The regression equation was used to extend the record of Reach C mean daily flows to the five-year record of the Reach A gage.

Climatic Comparisons

To determine whether the 2002–2007 flow record was relatively normal, above average ("wet"), or below average ("dry"), USGS records for Iliamna River (Station 15300300) were compared to the Reach A gage record. The Iliamna River is the closest gage station with the longest term record (June 1996 through September 2009) coinciding with Reach A gage, but has a more maritime climate, a larger drainage area and higher elevation profile. Annual precipitation at Iliamna Airport (available from the National Climatic Data Center http://lwf.ncdc.noaa.gov/oa/ncdc.html from 1982 through 2010; missing years 1988, 1991–1993, 1997-1999) was also evaluated.

RESULTS

REACH A

On October 3, 2001, ADF&G, with the assistance of TNC, installed a gaging station at approximately river kilometer (rkm) 2.1 on the mainstem of Lower Talarik Creek. This gage was relocated to the opposite bank on July 27, 2002, due to aufeis and flooding that occurred during the first winter. The stage record prior to this move was very short and consequently not used for any streamflow computations. The gage was operated at the new location through September 27, 2007, and provided five years of record. Discharge measurements were made approximately three to four times per year and ranged from 96 to 348 cfs (Table 1). The stage record during open water periods had only a few 15-minute stage values missing. Ice cover occurred during the entire duration of most winters. Some periods such as during the winter of 2002–2003 were known to have open water, but mean daily flows were estimated because of the difficulty in determining if and to what degree stage was influenced by bank ice during these periods.

Two rating curves were developed. The first one was valid from July 27, 2002, to March 1, 2005. A second rating curve, valid for the remainder of the record, was needed because the stage-discharge relationship had changed, presumably from sedimentation that developed in the

[2] Under 11AAC 93.142, the applicant has three years from the date the ROW application is accepted to fully quantify the proposed reservation; at the applicant's written request, the DNR commissioner will, in his or her discretion, grant an extension of the time period of up to two years for good cause shown.

channel control over time. Some bank erosion just above the gage appeared to have also contributed to this sedimentation. By spring break-up in 2005, this change in channel control appeared substantial enough to warrant the second rating curve.

Mean of mean daily flows (Table 2) ranged from 124 to 295 cfs. Mean monthly flows (Table 3) ranged from 112 cfs in March 2007 to 341 cfs in October 2006. Monthly mean flows were fairly consistent within and among years with slightly higher values during the fall when most precipitation usually occurs. Mean annual flows were also fairly consistent ranging from 158 cfs in 2007 to 184 cfs in 2005 (Table 4). Monthly exceedance probabilities (Table 5) also reflect fairly low variability in flows within and among months.

REACH B

Seventeen discharge measurements were made at Reach B; fifteen of these were during the Reach A gage period, and two measurement pairs were made prior (Table 1). Measured discharge averaged approximately 48% of the Reach A measured discharge. Strong linear relationship existed between Reach B and Reach A discharge measurements with 97% of the variability in flows in Reach B explained by the model (Figure 3, Appendix A1). The regression results were only used to estimate mean of mean daily flows (Table 6), mean and mean of mean monthly flows (Table 3), and mean annual flows (Table 4). The regression of discharge measurements did not provide an adequate temporal basis for estimating duration values.

REACH C

The gage for Reach C was installed at the outlet of the West Lake on July 11, 2003, and operated until August 24, 2005. Six discharge measurements were made during the gage period and three prior to the gage record (Table 1). The primary transducer cable was destroyed on February 2, 2005, presumably by a wolverine or wolf that had chewed through the metal conduit and through the cable of the pressure sensor. The stage record after this point was determined by the backup transducer. The water temperature probe stopped working for an unknown reason on October 10, 2004, and was not replaced. The interpretation of winter records was particularly problematic due to frequent intervals of open water and ice cover. The cross section at the gage seemed to have greater periods of open water and, in fact, all winter discharge measurements were made in open water. However, the stage during the winter was still ice-affected, so most of the winter record was estimated rather than calculated based on a rating curve. Unfortunately, access to this site proved to be problematic, with a short take-off distance, and impossible during some wind directions, so not as many discharge measurement were made as desired.

A moderately positive linear relationship existed between Reach C and Reach A gage records with 53% of the variability in flows in Reach C explained by the model (Figure 4, Appendix A2). The regression parameters/results were combined with the gage record to construct an extended record of estimated mean daily and mean of mean daily flows (Table 7), estimated mean monthly flows (Table 3), estimated mean annual flows (Table 4), and monthly exceedance values (Table 8). Figures 5 and 6 shows hydrographs of mean daily flows for Reaches A and C with the five-years of gaged and extended records.

Mean daily water temperatures show typical seasonal and diurnal cycles (Figure 7). Key features of this temperature record are high peak temperatures exceeding 18 °C in 2003, 2004, and 2005 and unseasonably warm temperatures during the winter of 2003.

Climatic Comparisons

The mean annual flow from the Iliamna River gage record for the period coinciding with the Reach A record (2003 through 2007) was 4.3% above the longer-term average (Table 9). The slightly above-average annual flow during the study period seemed to be driven mostly by a warm winter with relatively high flows in February 2003 and extreme flooding during October and November 2002. Although these hydrological features are apparent in Lower Talarik Creek records, they appear to be major drivers of the mean annual flow statistics. Mean precipitation at the Iliamna Airport during the study period was nearly equal to the longer-term average (Table 10).

DISCUSSION

Difficult and costly access to study sites in the Lower Talarik Creek drainage hampered gaging efforts. Accuracy of all winter records should be considered "poor" due to the effects of ice cover and the lack of repeated winter measurements. Because the stage-discharge relationship is not valid during periods of ice cover, the winter record is based on very few discharge measurements. For the periods around breakup, accuracy is deemed "fair to poor" and for the remainder of the open water season for all years of record "fair to good."

Ideally, mean daily flows for Reach B would have been calculated by simply subtracting Reach C flows from Reach A. Estimating flows using the simple linear regression of discharge measurements was necessary for minimizing bias for two main reasons. First, most winter records on Reach C were calculated from a stage-discharge relationship. This caused an incongruence between winter flows estimates at the two reaches and would have resulted in some mean daily flows for Reach B being unrealistically negative or zero. Secondly, the extension of records of Reach C were based on two years of the gage record at Reach A, and this daily relationship was not as strong as desired (R^2=0.53). Reach B seemed hydrologically more similar to Reach A than Reach C, supplying a majority of the water at all but the lowest flows throughout the year.

Lower Talarik Creek streamflow had relatively little variability over the five years of record, which is commensurate with a low elevation relief (585 m maximum) and high groundwater sourcing. The lowest flows occurred during summer drought periods, and high flows occurred during the fall when most precipitation normally occurs in this region. Base or low flows in Reaches B and C appeared similar, despite the Reach B drainage area being 2.7 times greater than Reach C. Reach B also has more topographic relief and may therefore be more responsive to surface runoff occurring mostly during spring and autumn. Reach C flows during the gaged period had little seasonal variability, open water periods during the winter (while Reach A was ice-covered), and higher base flows relative to its drainage area indicating that it is less affected by overland runoff, and predominately fed by groundwater or interflow. Overall, these data strongly suggest that Lower Talarik Creek has a substantial and stable amount of ground-water input that buffers summer droughts and winter low flows, and that these hydrological features combined with abundant adjacent lake habitat may be instrumental in supporting high fish productivity.

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TABLES AND FIGURES

Table 1.–Summary of discharge measurements (cfs) made at study sites in the Lower Talarik Creek drainage.

Date	Reach A	Reach B	Reach C	East Lake
8/7/2000	179	69		68
10/3/2001	109			
2/28/2002	96	32		
7/27/2002	146	66		
7/28/2002	152	69		
7/29/2002			81	46
10/2/2002	188			
10/3/2002	177	86		
10/4/2002	181	84		
10/5/2002			71	73
2/26/2003	191	87		
7/9/2003			70	
7/10/2003	122	49		
10/1/2003	234	132		
10/3/2003			156	211
2/24/2004	151			
2/25/2004			82	
2/26/2004		71		
6/8/2004			89	73
6/9/2004	185	91		
10/1/2004	300	152		
10/3/2004			109	
5/1/2005			90	
5/2/2005	189	96		
8/24/2005			84	
8/25/2005	178			
3/23/2006	130			
6/20/2006	154	75		
9/25/2006	348	215		
2/22/2007	116			
6/6/2007	118	55		
9/27/2007	257	144		

Table 2.–Mean of the mean daily flows (cfs) for Lower Talarik Reach A, based on complete water years of record, October 1, 2002, through September 30, 2007.

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	146	136	138	125	169	143	137	130	185	270	262	197
2	145	132	140	130	165	142	138	128	182	295	259	196
3	144	132	138	130	161	141	135	126	180	294	253	195
4	143	136	137	130	159	140	135	133	188	293	247	191
5	143	135	134	132	158	139	135	135	189	288	250	186
6	142	134	134	133	159	139	136	136	189	283	259	190
7	141	137	133	138	158	138	135	133	182	284	255	193
8	140	150	132	137	157	137	135	128	191	281	252	189
9	139	146	132	135	158	143	139	126	217	274	248	184
10	139	145	131	137	163	143	135	125	218	269	245	185
11	138	143	132	139	161	143	138	130	211	268	242	182
12	137	143	132	140	160	141	144	134	220	267	229	171
13	136	141	132	144	158	139	141	137	213	261	225	169
14	135	139	132	146	156	136	140	137	218	255	222	166
15	134	136	131	161	154	135	136	144	224	255	230	164
16	135	133	130	172	152	136	136	144	222	258	254	162
17	135	132	128	163	151	139	135	141	214	257	226	161
18	135	133	127	161	148	139	135	141	205	256	217	160
19	136	133	128	157	147	142	134	151	216	264	226	159
20	137	133	127	162	146	140	131	159	227	259	213	158
21	138	134	129	163	145	138	131	158	222	266	225	155
22	138	133	130	163	144	137	131	160	235	269	212	155
23	137	134	128	165	150	136	129	162	251	278	214	154
24	138	134	127	161	149	140	133	162	249	267	214	153
25	133	133	127	169	149	142	133	166	246	283	205	152
26	135	134	126	169	149	140	137	172	244	270	210	150
27	131	134	125	175	149	137	135	173	238	289	204	149
28	138	140	124	170	150	136	135	192	248	270	202	149
29	139	[a]	124	176	148	134	133	193	265	260	201	148
30	139		124	173	146	134	131	190	279	269	200	148
31	137		126		144		132	190		265		147

[a] Mean of February 29th included in 28th.

Table 3.–Mean monthly flow (cfs) for Lower Talarik Creek Reach A, B, and C, based on complete months of record, August 1, 2002, through September 30, 2007.

Reach A

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002								155	173	224	244	198
2003	165	166	136	135	126	119	125	136	149	253	195	158
2004	145	151	149	184	205	165	140	128	155	245	298	193
2005	128	127	133	156	153	138	149	168	319	294	210	152
2006	133	121	122	129	149	146	135	186	283	341	204	141
2007	119	118	112	156	134	127	126	130	186			
Mean of Mean	138	136	130	152	154	139	135	151	211	271	230	168

Reach B

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002								69	82	118	132	99
2003	76	77	55	55	48	43	47	55	65	139	97	71
2004	62	66	64	89	105	76	58	49	69	133	171	96
2005	50	49	53	70	67	56	65	78	186	168	108	67
2006	53	44	45	50	65	62	54	91	160	202	104	59
2007	43	42	38	69	54	49	48	51	91			
Mean of Mean	57	56	51	67	68	57	55	66	109	152	122	78

Reach C

Calendar Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002								79	82	93	97	88
2003	81	81	75	74	73	71	75	73	69	97	90	74
2004	68	87	91	100	95	87	80	75	76	96	103	80
2005	66	63	71	86	79	76	73	73	113	108	90	78
2006	74	71	72	73	77	77	74	85	105	117	89	76
2007	71	71	70	79	74	73	72	73	85			
Mean of Mean	72	75	76	82	80	77	75	76	89	102	94	79

Table 4.–Mean annual flow (cfs) by water year for Lower Talarik Creek, Reaches A, B, and C.

Water Year	Reach A	Reach B	Reach C
2003	160	73	79
2004	169	79	85
2005	184	90	82
2006	172	81	82
2007	158	71	79
Mean	169	79	81

Table 5.–Monthly duration flows (cfs) for Lower Talarik Creek Reach A, based on complete months of record, August 1, 2002, through September 30, 2007.

% Time exceeded	January	February	March	April	May	June	July	August	September	October	November	December
0	181	235	168	265	256	179	176	290	392	405	463	270
5	173	175	155	209	213	170	159	225	359	362	321	240
10	168	157	150	202	204	165	150	211	331	351	292	223
15	165	154	147	192	192	161	147	176	312	335	278	207
20	153	151	144	181	178	152	143	166	294	324	269	181
25	147	150	141	168	164	151	141	159	273	309	261	174
30	145	149	137	156	155	148	139	155	246	302	252	173
35	141	146	136	153	153	144	137	150	225	295	243	168
40	137	138	133	150	152	142	137	147	205	290	236	164
45	134	132	131	146	150	140	136	145	193	286	230	162
50	133	126	129	141	147	138	135	143	183	274	230	161
55	131	125	125	139	145	136	134	141	173	260	224	158
60	130	121	124	135	143	134	132	139	166	247	212	156
65	128	121	123	131	139	131	130	136	160	236	199	154
70	126	120	121	130	136	129	128	133	156	228	195	151
75	124	120	121	130	132	125	126	128	150	219	187	149
80	121	119	117	129	129	122	125	124	145	215	185	147
85	119	118	114	127	125	121	123	120	140	211	179	145
90	119	118	113	126	122	117	120	116	136	203	173	137
95	118	117	110	119	117	113	117	110	128	196	165	128
100	118	115	105	106	113	111	111	104	115	175	164	122

Table 6.–Mean of the mean daily flows for Lower Talarik Reach B, based on regression of discharge measurements and extension of gage records of complete water years from Reach A, October 1, 2002, through September 30, 2007.

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	65	58	59	50	80	63	59	54	90	148	143	99
2	64	55	60	54	77	62	59	52	87	165	141	99
3	63	55	59	54	75	61	57	51	85	165	137	98
4	63	58	58	54	73	61	57	54	89	164	133	95
5	63	57	57	55	73	60	57	56	91	161	135	92
6	62	56	56	56	73	59	58	58	90	157	141	95
7	61	59	56	59	73	59	57	55	86	158	138	97
8	60	67	55	59	72	58	57	53	92	156	136	94
9	60	65	55	57	72	62	60	52	107	152	134	90
10	59	64	55	59	76	62	57	52	106	148	132	91
11	59	63	55	60	75	62	59	58	102	147	130	89
12	58	63	55	61	74	61	63	59	109	147	121	82
13	57	61	55	63	73	60	61	60	109	142	118	80
14	57	60	55	64	71	58	60	61	111	139	116	78
15	57	58	54	75	70	57	58	64	114	138	122	77
16	57	56	54	82	68	57	57	65	111	140	138	75
17	57	55	53	76	68	60	57	61	107	140	119	74
18	57	56	51	75	66	60	57	61	101	139	113	74
19	57	56	52	72	65	61	56	67	108	144	119	73
20	58	56	52	76	65	61	55	75	113	141	110	73
21	59	56	53	76	64	59	54	80	109	146	118	71
22	59	55	54	76	63	58	54	81	116	148	109	71
23	59	56	52	77	67	58	53	81	127	154	111	70
24	59	57	52	75	67	61	56	79	127	147	111	69
25	56	56	51	80	66	62	56	80	125	157	105	68
26	57	56	51	81	66	61	58	81	125	149	108	67
27	54	56	50	84	67	58	59	81	122	161	104	67
28	59	60	50	81	67	57	60	92	127	149	102	67
29	60	[a]	49	85	66	56	58	92	137	142	102	66
30	60		50	83	64	56	56	92	146	148	101	65
31	59		51		63		55	93		146		65

[a] Mean of February 29th included in 28th.

Table 7.–Mean of the mean daily flows for Lower Talarik Reach C, from gaged and extended records of complete water years, October 1, 2002, through September 30, 2007.

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	75	72	78	72	86	78	77	75	82	106	97	91
2	75	73	80	73	84	77	78	74	82	115	98	91
3	75	74	80	73	82	77	77	72	81	115	97	85
4	75	74	80	74	82	77	77	73	83	111	96	84
5	74	73	79	74	80	77	76	74	83	108	97	83
6	74	72	78	77	81	76	76	74	83	106	98	83
7	73	73	77	81	83	76	75	73	82	105	96	83
8	72	76	77	82	83	76	75	72	83	103	95	82
9	73	75	76	82	82	78	75	71	89	101	94	82
10	72	75	76	82	81	77	74	70	89	100	93	82
11	71	75	76	83	81	77	75	71	88	100	93	81
12	71	75	76	82	80	77	77	72	90	100	90	79
13	71	76	77	83	79	77	76	74	89	99	89	78
14	72	76	77	82	78	76	75	74	90	98	89	77
15	72	75	76	84	78	75	74	75	91	98	90	77
16	71	75	76	86	77	76	74	75	90	99	89	77
17	70	75	76	85	78	76	74	74	89	99	89	77
18	70	72	73	84	79	77	74	74	86	97	90	77
19	69	75	66	83	78	80	76	78	89	99	92	76
20	70	75	71	85	78	80	74	78	93	97	94	76
21	70	75	78	86	78	78	74	78	92	102	96	75
22	70	75	79	87	78	76	73	77	94	102	96	75
23	71	75	78	88	78	76	72	77	98	101	96	76
24	71	75	76	87	79	77	73	78	97	102	96	76
25	70	75	75	86	79	77	74	83	95	101	96	76
26	71	75	73	86	79	77	75	82	96	101	94	75
27	65	76	73	86	78	75	76	81	94	106	94	75
28	69	79	72	86	78	75	76	81	96	102	94	75
29	77	[a]	72	87	79	75	75	81	100	100	94	76
30	77		71	88	78	75	74	79	107	97	93	75
31	73		72		78		74	79		98		75

[a] Mean of February 29th included in 28th

Table 8.–Monthly exceedance flows (cfs) Lower Talarik Creek, Reach C, based on complete months of the combined gage and extended flow records, August 1, 2002, through September 30, 2007.

% Time exceeded	January	February	March	April	May	June	July	August	September	October	November	December
0	106	95	114	126	120	94	86	98	134	159	123	121
5	82	91	101	106	100	89	84	93	122	123	108	96
10	81	90	92	103	92	87	82	87	116	120	107	84
15	80	88	81	99	90	85	81	83	111	117	104	83
20	78	83	77	95	86	83	79	80	108	114	102	82
25	76	80	75	89	82	78	77	79	103	110	99	81
30	74	78	74	87	79	78	76	78	98	109	98	80
35	73	77	73	84	78	77	75	77	93	107	97	80
40	72	74	72	82	78	76	75	76	90	107	96	79
45	72	71	72	79	78	76	74	76	87	106	95	79
50	71	71	72	77	78	75	74	75	85	104	94	78
55	71	71	71	75	77	75	74	74	82	100	94	78
60	71	71	71	74	76	74	73	74	80	96	93	77
65	71	71	71	74	75	73	73	73	79	92	91	76
70	70	71	70	73	74	72	73	72	76	91	88	75
75	68	71	70	73	74	72	72	71	72	90	86	74
80	66	70	70	73	73	72	72	71	71	89	85	73
85	64	67	70	73	72	71	71	70	69	87	83	72
90	63	64	69	72	72	70	71	68	68	86	81	72
95	60	62	68	71	71	70	70	66	68	85	80	70
100	42	49	43	68	70	69	65	62	65	69	71	65

Table 9.–Mean annual flow (cfs) by water year for Iliamna River, USGS gage station 1500000 and percent difference of annual mean to mean for entire record.

Water year	Mean flow	Percent difference
1997	622	-32
1998	1,083	19
1999	874	-4
2000	776	-15
2001	1,017	12
2002	834	-8
2003	1,188	31
2004	996	10
2005	908	0
2006	870	-4
2007	889	-2
2008	911	0
2009	843	-7
Mean 2003-2007	970	7
Mean of all years	909	

Table 10.–Mean annual precipitation (in) at Iliamna Airport. Data from the National Climatic Data Center.

Year	Precipitation
1982	26.7
1983	24.6
1984	19.2
1985	40.8
1986	31.4
1987	23.8
1989	30.5
1990	25.5
1994	25.1
1995	17.2
1996	20.9
2000	28.0
2001	25.0
2002	28.7
2003	28.7
2004	27.2
2005	29.0
2006	15.9
2007	22.7
2008	21.5
2009	21.0
2010	24.3
Mean	25.3
2002-2007 Mean	25.4

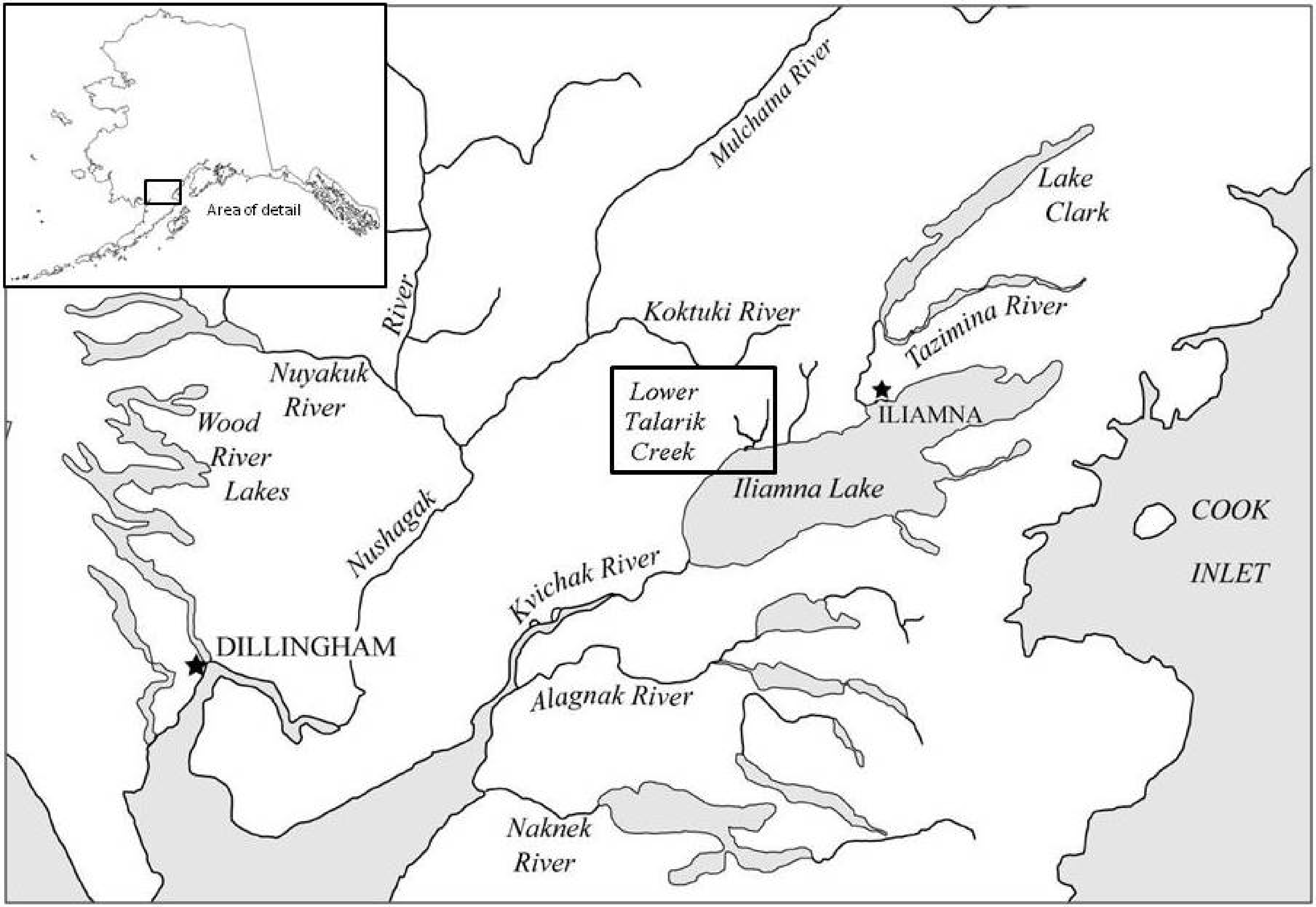

Figure 1.–Map showing location of Lower Talarik Creek in southwestern Alaska.

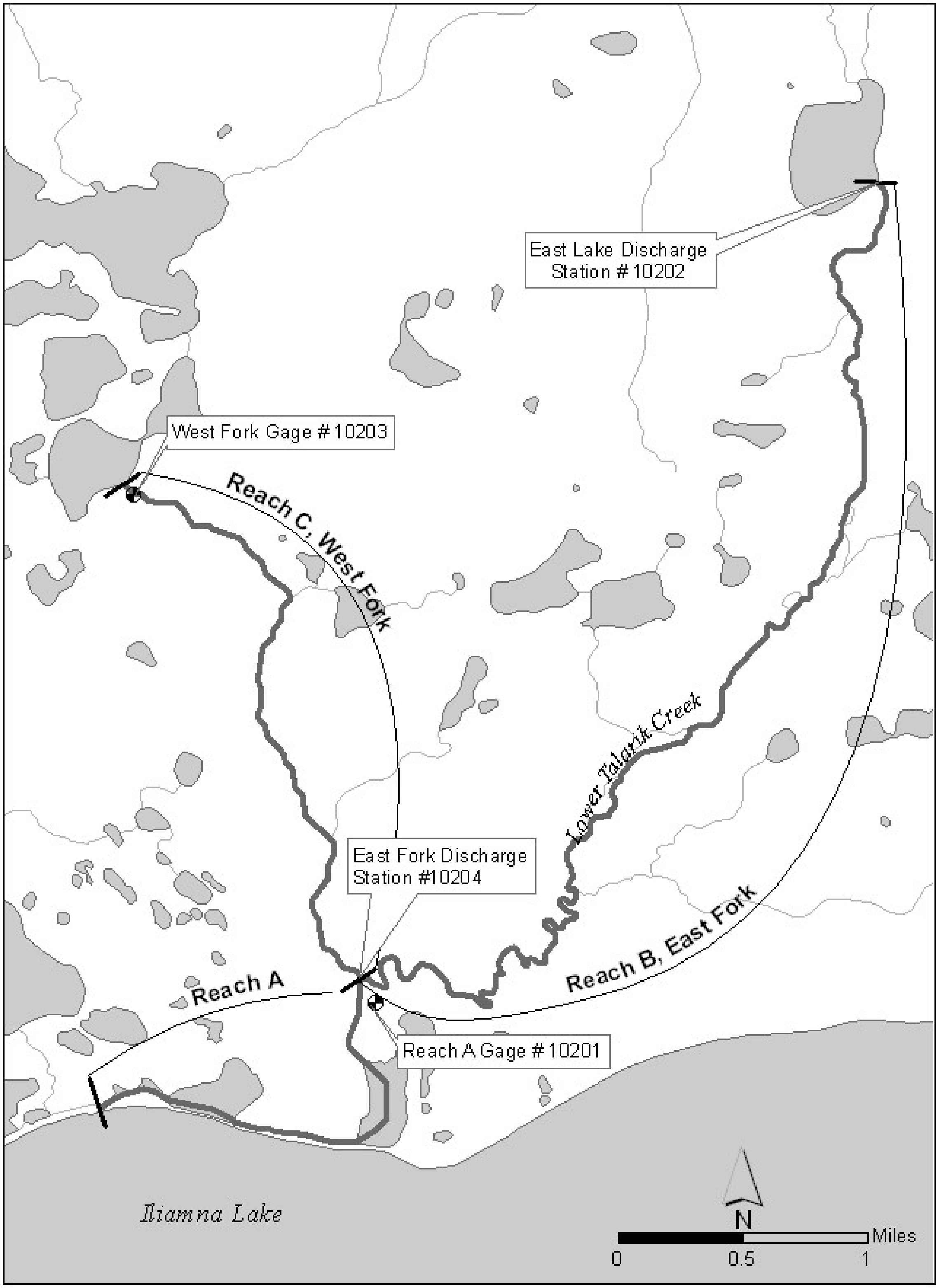

Figure 2.–Lower Talarik Creek study site and locations of gage and discharge measurement stations and reservation of water reaches.

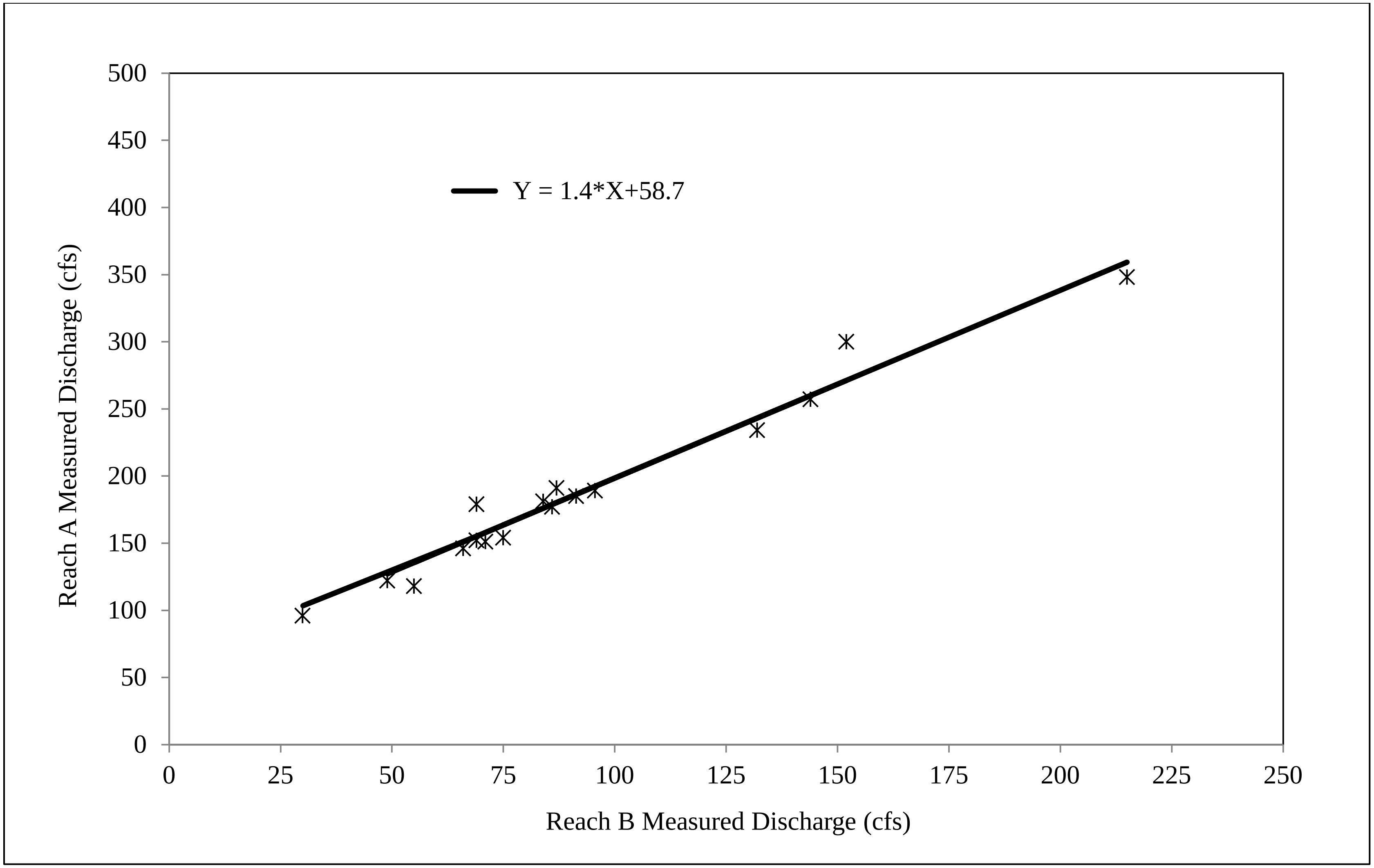

Figure 3.–Regression relationship between discharge measurements taken at Reach A gage site and Reach B.

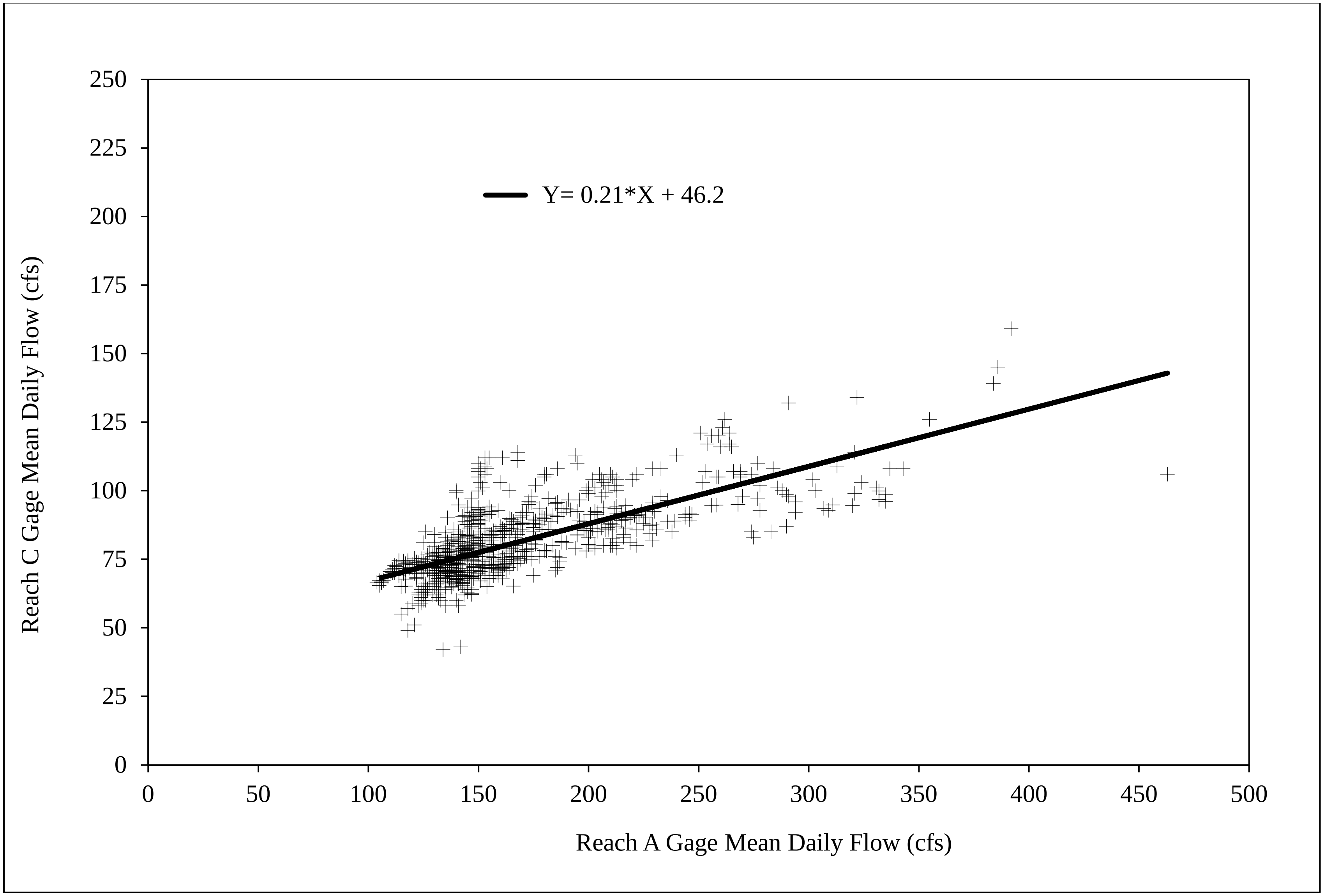

Figure 4.–Regression relationship of mean daily flows from the Reach A and C gages during the coinciding gage record, July 11, 2003, through August 24, 2005.

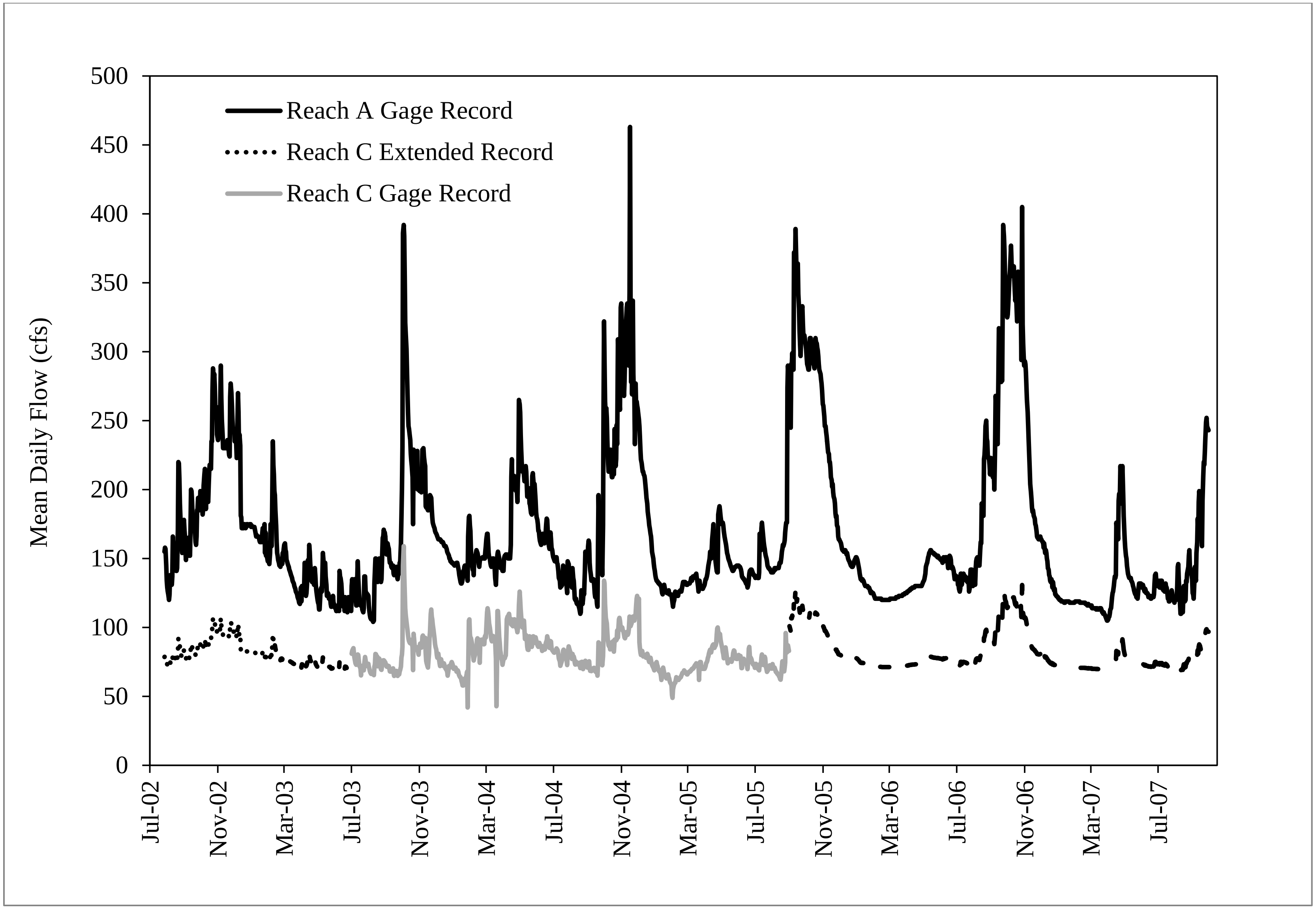

Figure 5.–Hydrograph of mean daily flows for Reach A gage and Reach C gage including extended flows for entire period of record, July 27, 2002, through September 30, 2007.

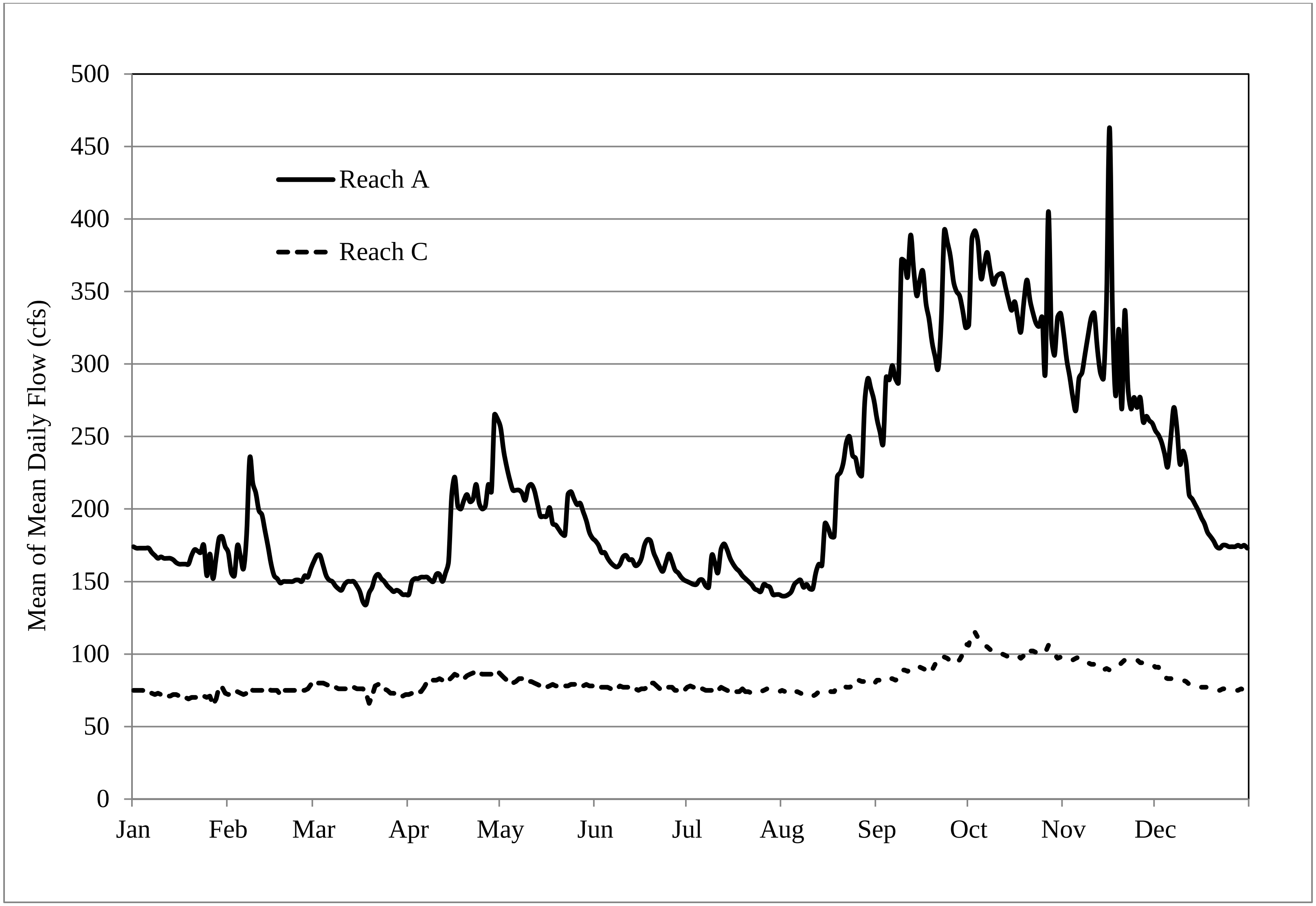

Figure 6.–Hydrographs of the mean of mean daily flows for Lower Talarik Creek Reach A and C, based on entire period of record, July 27, 2002, through September 30, 2007.

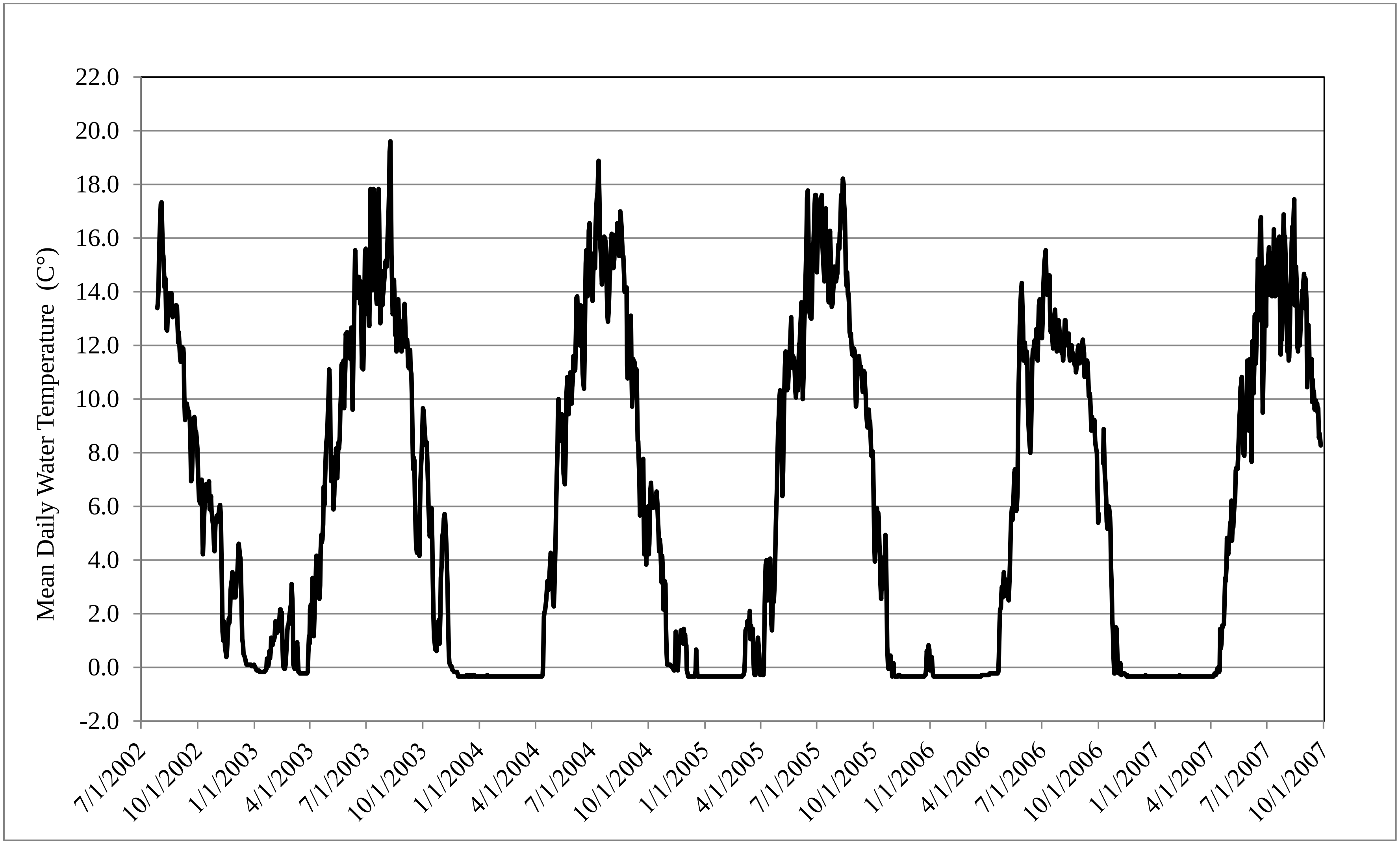

Figure 7.–Mean daily water temperatures (°C) at the Lower Talarik Creek Reach A gage, July 27, 2002, through September 27, 2007.

APPENDIX A: RESULTS OF REGRESSION OF DISCHARGE MEASUREMENTS FROM REACHES A AND B, TO EXTEND RECORDS FOR REACH B

Appendix A1.–Results of regression of discharge measurements from Reaches A and B, to extend records for Reach B.

Regression Statistics	
Multiple R	0.98
R Square	0.97
Adjusted R Square	0.97
Standard Error	8.50
Observations	17

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	31611.20	31611.20	437.73	0.00
Residual	15	1083.24	72.22		
Total	16	32694.44			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-34.59	6.41	-5.40	0.00	-48.25	-20.92
X Variable	0.68	0.03	20.92	0.00	0.61	0.75

Appendix A2.–Results of regression of gage records from Reaches A and C, to extend records for Reach C.

Regression Statistics	
Multiple R	0.73
R Square	0.53
Adjusted R Square	0.53
Standard Error	9.59
Observations	793

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	81605.98	81605.98	886.78	0.00
Residual	791	72791.77	92.02		
Total	792	154397.75			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	46.15	1.22	37.92	0.00	43.76	48.53
X Variable	0.21	0.01	29.78	0.00	0.20	0.22

APPENDIX B: ADF&G GAGE AND DISCHARGE STATION AVAILABLE DATA FILES

Appendix B1.–The following data used for this report are stored in the WISKI© database and are available upon request.[1]

Database Reference	Description
Reach A, Gage Station 10201	
LTC.Main.Q.DayMean.E	Mean daily flows from 07/27/2002 to 09/30/2007
LTC.Main.Q.Obs.Q	Instantaneous discharge measurements from 07/27/2002 to 09/27/2007
LTC.Main.WT.240	Water temperature at 4-hour intervals from 07/27/2002 to 09/26/2007
Station Description	Detailed summary of gage location, equipment, benchmarks, access, and other interesting details
Station Analysis	Detailed summary gage operation and stream flow computations, ratings, etc
Reach B, Discharage Station 10203	
LTC.EFRK.Q.DayMean.E	Regression estimate of mean daily flows from 07/27/2002 to 09/30/2007
LTC.EFRK.Q.Obs.Q	Instantaneous discharge measurements from 07/27/2002 to 09/27/2007
Reach C, Gage Station 10203	
LTC_W_FK.Q.DayMean.E	Mean daily flows from 07/27/2002 to 09/30/2007 (includes extended flows)
LTC_W_FK.Q.Obs.Q	Instantaneous discharge measurements from 07/29/2002 to 08/24/2005
LTC_W_FK.WT.240	Water temperature at 4-hour intervals from 07/09/2003 to 10/09/2004
Station Description	Detailed summary of gage location, equipment, benchmarks, access, and other interesting details
Station Analysis	Detailed summary gage operation and stream flow computations, , ratings, etc.

[1] Contact ADF&G Division of Sport Fish, Research and Technical Services, 333 Raspberry Rd, Anchorage, AK 99518.

APPENDIX C: PHOTOGRAPHS OF DISCHARGE MEASUREMENT TRANSECTS

Appendix C1.–Photos of discharge measurement transects.

Reach A, looking downstream from ADF&G gage station 10201 taken on June 6, 2007, at a discharge of 118 cfs.

Reach B, ADF&G station 10204 looking upstream from downstream boundary, taken on June 6, 2007, at a discharge of 55 cfs.

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Looking downstream from ADF&G gage station 10203, near the upper boundary of Reach C, taken on August 24, 2005, at a discharge of 84 cfs.

An example of a trophy rainbow trout from Lower Talarik Creek (photo by Craig Schwanke, ADF&G).