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# Water Resources and Channel Geometry of Birch Creek National Wild River, Alaska

Jon Kostohrys



**BLM**

Alaska



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### **Author**

Jon Kostohrys, a former hydrologist with the BLM's Fairbanks District Office, retired in December 2005. During his career with the BLM, Jon researched and authored 10 other publications. He significantly contributed to the protection of BLM-managed National Wild and Scenic Rivers and other waters for fish, wildlife, and the enjoyment of future generations.

### **Cover**

Autumn foliage and Birch Creek National Wild River. BLM photo by Holli McClain

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222 W. 7th Ave., #13  
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## Abstract

Birch Creek is a clear-water tributary of the Yukon River in the interior of Alaska. Surrounded by rugged uplands with scenic rocky bluffs in the headwaters, the watershed has significant sports fisheries and a variety of recreational river opportunities. These attributes were recognized in a congressional designation of Birch Creek as a National Wild River on December 2, 1980. The Bureau of Land Management (BLM) began a water rights and instream flow study in 1989 to protect these free-flowing waters. An application for water rights, based on the hydrologic data collected from 1989 to 1994 (Kostohrys and Sterin 1996) and the resource values documented by Sterin et al., (1998), was accepted by the State of Alaska, Department of Natural Resources on January 11, 2001. There were five or more years of data included in the application, although one gaging site with less data was largely estimated from regression equations based on nearby gages. The BLM continued to collect water resources data from 1995 to 2000 to fill this void as well as to obtain 10 years of record. This report documents the data from the latter period as well as the statistical analysis on all data combined for the entire period of record. This analysis indicated that updating the instream flow application with the data in this report may not be necessary. Riparian surveys of channel geometry to determine bankfull stream characteristics were also conducted on Birch Creek and its tributaries. These surveys documented the peak floods and impacts of mining runoff, and were used to calculate regional equations for channel design in placer mining reclamation.

## Acknowledgments

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Special thanks to contract pilot Sandy Hamilton, whose flying skills brought us back at times when things looked grim. Kristine Kosnik did the GIS analysis and Carol Belenski produced the maps. Ingrid McSweeney, Larry Standley, and Lee Koss secured the funding to complete this report.

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## INTRODUCTION





The Alaska National Interest Lands Conservation Act of December 2, 1980, (ANILCA, P.L. 96-487) established the upper portion of Birch Creek as a component of the National Wild and Scenic Rivers System. Approximately 126 miles of the upper river were classified “wild” pursuant to the Wild and Scenic Rivers Act. BLM-Alaska’s river management plan for Birch Creek National Wild River specifies that “a reservation of minimum water flows sufficient for public recreation use and to support the values for which the wild river was designated will be determined in cooperation with the Alaska Department of Natural Resources Division of Land and Water Management” (BLM 1983). The watershed has significant sports fisheries, scenic bluffs and bedrock outcrops, and a variety of recreational river opportunities. The river management plan provided the impetus for a water rights assessment of the Birch Creek National Wild River.

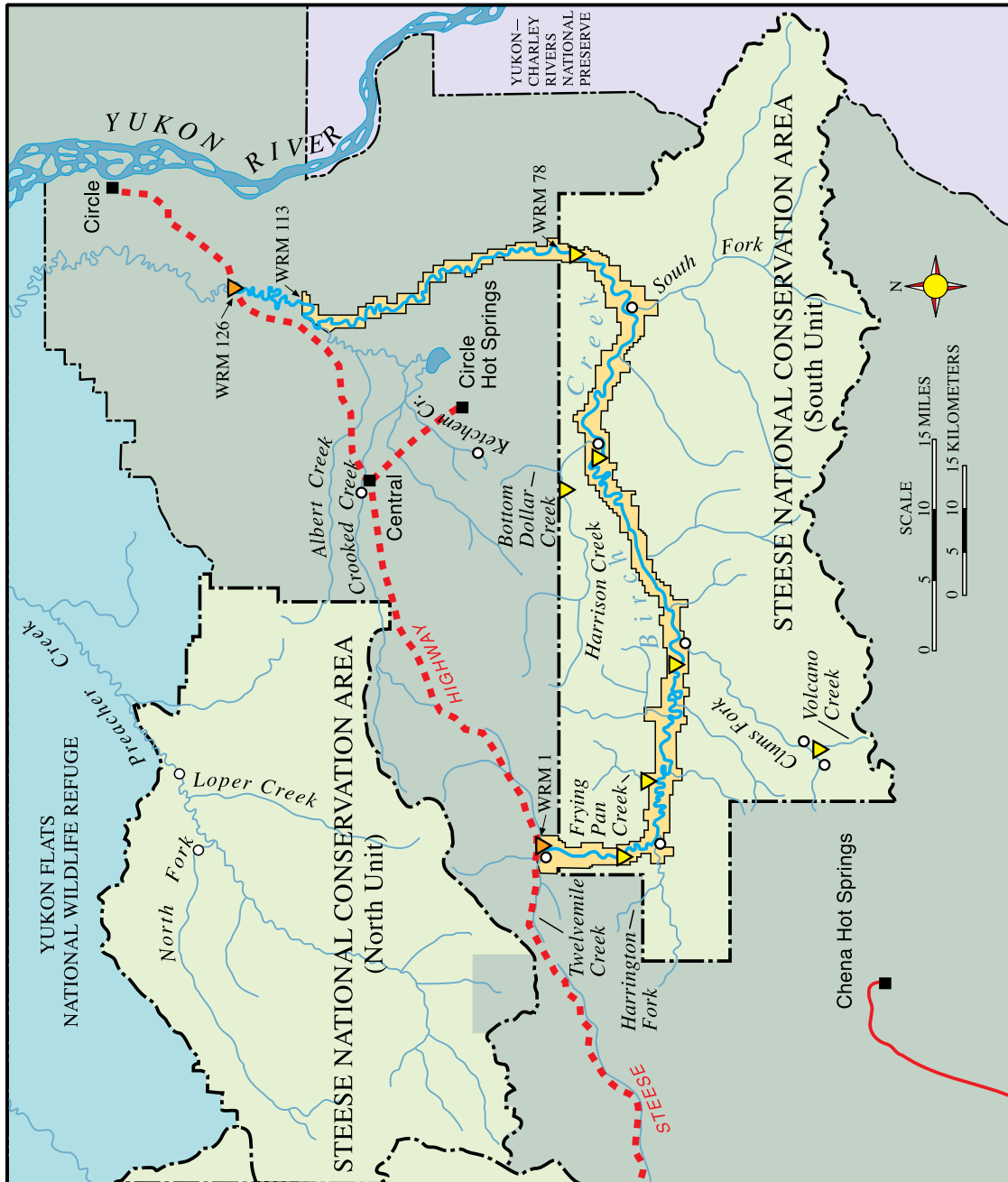
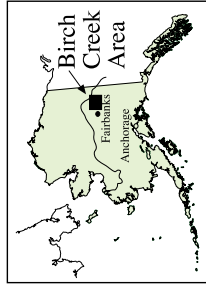
BLM-Alaska initiated a water resources inventory for the purpose of preparing a water rights assessment document in 1989. The intent was to apply for a state water right for instream flow following the computation of the hydrologic data and evaluation of all the resource information. The BLM published a water resources inventory for Birch Creek (Kostohrys and Sterin, 1996). A more comprehensive instream flow analysis (Sterin et al., 1998) was conducted to address the resource values identified in the river management plan. An application for water rights was filed with the State of Alaska, Department of Natural Resources (DNR), in January 2001 and is currently pending.

This report summarizes the streamflow for the entire period of record, documenting the statistical analysis of all data from 1989 to 2000 on Birch Creek, and completes a 10-year period of data collection. Also included are a number of stream channel monitoring sites established during this period to determine flood discharges and bankfull channel characteristics. These sites were usually located in areas impacted by placer mining to assess impacts and provide data for channel reclamation. This data provides managers and resource specialists with the knowledge necessary for informed management, to assess impacts from mining runoff and evaluate channel design information for placer mining reclamation.

This report covers the 126 miles of Birch Creek (**Figure 1**) included in the National Wild and Scenic Rivers System, beginning approximately one mile upstream of the confluence with Twelvemile Creek, River Mile 0, and ending at the Steese Highway Bridge, River Mile 126. A number of the tributary streams in the Birch Creek basin are also included to document the flooding and channel geometry changes that occurred during the study period.

# Birch Creek National Wild River

-  State of Alaska Department of Natural Resources Gages
-  Bureau of Land Management Gages
-  Channel Geometry Survey Sites
-  Birch Creek National Wild River Corridor



## DESCRIPTION OF THE STUDY AREA

### Physiography

The Birch Creek watershed is located in the eastern interior of Alaska. This basin is part of the Yukon-Tanana upland, an area characterized by rounded, even-topped ridges with moderate-to-gentle side slopes (Wahrhaftig 1965). The wide river valleys, often heavily forested, are separated by more sparsely vegetated and compact, rugged mountains 4,000 to 5,000 feet in elevation. Intervening valleys, narrow in the headwaters, widen down valley into extensive marshy wetlands, sloughs and black spruce muskeg. The floodplain, consisting largely of reworked outwash gravel, silt, and organic materials is poorly drained and often underlain by discontinuous permafrost. The region is ultimately drained by the Yukon River.

A succinct summary of the basin is given by Ellsworth and Davenport in their original surveys of the watershed (USGS 1915):

“Birch Creek is formed by the junction of Eagle and Ptarmigan creeks and flows southwestward for about 7 miles to the mouth of Twelvemile Creek, where it turns abruptly to the south and follows that direction for about 8 miles. It then receives the waters of Harrington Fork and takes an easterly course for about 45 miles to its confluence with the South Fork. The river then makes a sharp turn north and about 12 miles farther on leaves the mountainous country and enters the lowlands of the Yukon, through which it meanders sluggishly for over 100 miles, roughly paralleling the Yukon. . . . Birch Creek flows into the Yukon River . . . about 25 miles directly west of Fort Yukon.”

Much of the uplands and some valleys are underlain by Precambrian to Tertiary metasedimentary rocks, while the higher mountains, consisting of younger intruded granitic rocks, show evidence of localized Pleistocene glaciation (Pewe et al., 1967). The dendritic drainage pattern of the area is controlled by the northeastward trend of the bedrock structures. The lowlands are underlain by unconsolidated floodplain deposits, river terraces, alluvial fans, dunes and lake deposits. Much of this material was deposited during the Pleistocene, when local alpine glaciers provided higher streamflow with greater erosional and depositional processes. This resulted in localized areas of placer mineral deposition, principally gold, throughout the basin (Mertie 1937). Localized areas of placer gold mining have been ongoing in the Birch Creek watershed from the gold rush of the early 1900s until the present.



**Photo 1.** Birch Creek—high stream flow following Spring breakup

## Climate

The Birch Creek basin lies in the subpolar continental climatic zone: long cold winters and short hot summers. Temperature extremes range from -70 degrees Fahrenheit in winter to +90 degrees Fahrenheit in summer. Precipitation averages 10 to 20 inches per year at nearby recording stations, although variations are great due to surrounding topography. Precipitation is generally greater at higher elevations in the headwater and decreases down valley into the Yukon flats (Jones and Fahl 1994).

During the summer, storms can produce intense rainfall from late June to early September and cause localized flooding (Childers et al., 1972). Snowfall averages roughly 50 inches per year (NRCS 2006), with about 20 inches remaining on the ground prior to Spring breakup, which usually begins in late April to mid-May. Freeze-up often begins at higher elevations in mid-September, although some streams lower in the basin remain open until November. Ice cover on the rivers is usually continuous during the winter except in the vicinity of springs, and freezing to the bottom may occur in places.

## METHODS

### Hydrology

The BLM continued the stream-gaging program as described in Kostohrys and Sterin (1996) until 1995, when an additional gage was added above Clums Fork. These sites (**Table 1**) consisted of an automated water level recorder downstream of the South Fork, and crest-stage gages—non-automated gages that record water levels that exceed a minimum (base) elevation—at the other locations. A water level recorder was placed at the Clums Fork site in 1998 and 1999.

The Alaska Division of Mining, Lands and Water operated two stream gages on Birch Creek, one above Twelvemile Creek and one at the Steese Highway Bridge. The State discontinued operation at the end of 1995. After the State's gages were discontinued, the BLM winter flow measurements at these sites were used to estimate the minimum winter discharge from 1996–1999, rather than to help compute the entire year, as was done in the 1989–1994 study.

**Table 1.** Location and Drainage Area of Long-term Gage Sites on Birch Creek and Tributaries

| <b>Gaging Site Location<br/>Birch Creek</b>         | <b>Site at Wild<br/>River Mile</b> | <b>Length<br/>of Reach<br/>(mi)</b> | <b>Drainage<br/>Area<br/>(sq mi)</b> | <b>Latitude</b> | <b>Longitude</b> |
|---|------------------------------------|-------------------------------------|--------------------------------------|-----------------|------------------|
| <b>Birch Creek<br/>above Twelvemile Creek*</b>      | 1                                  | 1                                   | 85                                   | 65.3267         | -147.7433        |
| <b>Birch Creek<br/>below Twelvemile Creek</b>       | 6                                  | 9                                   | 156                                  | 65.3267         | -147.7433        |
| <b>Birch Creek above Clums Fork</b>                 | 34                                 | 24                                  | 436                                  | 65.2670         | -147.2347        |
| <b>Birch Creek<br/>above Harrison Creek</b>         | 54                                 | 34                                  | 763                                  | 65.3533         | -147.7873        |
| <b>Birch Creek below South Fork</b>                 | 77                                 | 17                                  | 1350                                 | 65.3567         | -147.2850        |
| <b>Birch Creek<br/>at Steese Highway Bridge*</b>    | 126                                | 40                                  | 2150                                 | 65.3567         | -147.2850        |
| <b>Tributaries</b>                                  |                                    |                                     |                                      |                 |                  |
| <b>Frying Pan Creek near mouth</b>                  | NA                                 | 2                                   | 21                                   | 65.2808         | -147.5608        |
| <b>Volcano Creek near mouth</b>                     | NA                                 | 1                                   | 6                                    | 65.1267         | -147.4750        |
| <b>Harrison Creek<br/>above Bottom Dollar Creek</b> | NA                                 | 3                                   | 80                                   | 65.3800         | -147.8333        |

\*Stream gages operated by the Alaska Division of Mining, Lands and Water

NA: Not Applicable

At each field site inspection, gages were surveyed to reference elevation benchmarks, significant high-water marks, and the current water level, as noted in Benson and Dalrymple (1967). Cross sectional discharge (metered streamflow) measurements were made using a Price AA current meter to directly measure water velocity and a top-setting wading rod and tag line were used for depth and width (Rantz et al., 1982). Winter measurements were made by drilling a series of holes in the ice to define the cross section and then measuring the depth and velocity in each hole using a vertical-axis, vane-type current meter mounted on a graduated rod (Rantz et al., 1982). At most gaging sites from 1989 to 1994, multiple cross sections were surveyed to determine peak discharge using the slope-area method (Dalrymple and Benson 1967). At other sites from 1995 to 2000, the single cross section (slope-conveyance) method was used to calculate the flood peak discharge, as described in Parsons and Hudson (1985).

Both direct (metered streamflow) and computer-generated (indirect) discharge measurements were used to develop discharge rating curves—log-log regression relationships of water level versus discharge (Rantz et al., 1982). These rating curves were then used to directly compute the daily discharge tables and peak and minimum values developed for each data logger site.

Although the peak and minimum values were computed in the same manner at crest-stage gages, computation of average monthly discharge at these sites were determined by regression analysis of data logger records from the nearest reference gage with the most reliable record (Thomas 1967). For 1995–1998, the gage below South Fork was used as the reference site. In 1999, the site above Clums Fork was used as the reference site. Periods of no data, generally during April and May when the water levels fluctuate rapidly due to the effects of ice, snow and spring run-

off, are estimated from regression comparisons with the USGS gaging data on the Salcha River (USGS 1995–2000).

Streamflow for the winter period was estimated using recession curves derived from under-ice discharge measurements. One set of measurements was run in late fall/early winter and another in late winter/early spring to define the fall recession and winter low flow, respectively. Log-linear regressions of discharge on time (date) were collected for all sites to estimate the winter period, generally October through March. Since streamflow recession curves often take the form of exponential decay, discharge is then expressed as a constant times the initial discharge raised to a negative power of the time interval (Chow et al., 1988).

This methodology assumes that once ice and snow cover isolate the stream from precipitation and temperature changes, the flow to the stream recedes uniformly as the water table in the aquifer is lowered by reduction of water volume in the aquifer (Rogers and Armbruster 1990). Accuracy of winter determinations is low; as discharge approaches zero, flow measurements become unreliable because the water velocity diminishes below the measuring range (threshold velocity) of the instrumentation, while slush (frazzle) ice can pack beneath the ice surface and block velocity readings altogether for much of a stream reach.

### **Channel Geometry**

The channel geometry data collected very early in the study was originally intended to determine peak discharges at the instream flow gages on Birch Creek. These early cross sections were then compared to resurveys in 1994 at the same sites, and later riparian surveys at additional sites, conducted from 1995 to 2000. The intent of the resurveys was to determine the bankfull channel characteristics, magnitude of flooding, and whether significant erosion or deposition had occurred. Since some of the streams were impacted to some extent by placer mining, the alteration of riparian conditions or channel geometry changes that occurred during the study period might be used to assess or improve mining reclamation. The initial surveys were conducted using a total station theodolite, but later on, transit-stadia surveys were employed using a surveyor's level, stadia rod, and measuring tape.

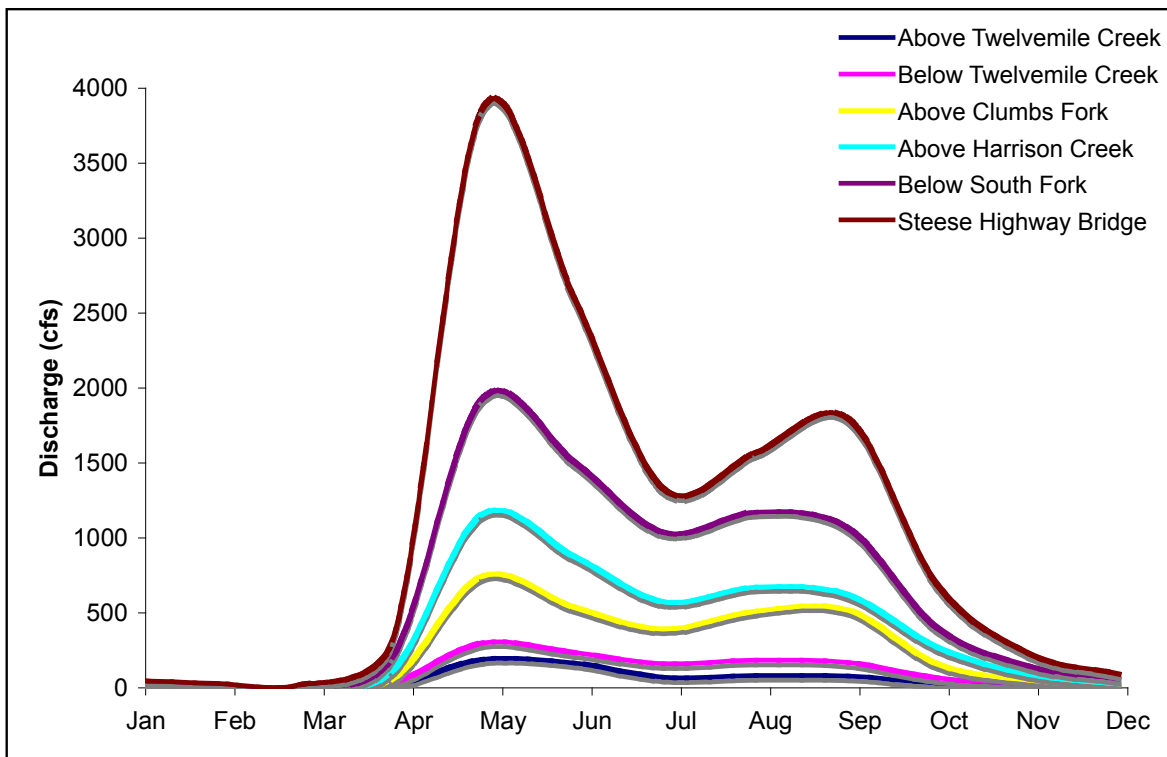
For this study, the main consideration was to locate a straight reach of channel where flows are uniform. This often occurs in the cross-over area, a relatively straight section mid-way between meander bends. The reference elevation used to define the bankfull characteristics was chosen mainly to reflect a discharge sufficient to fill the main channel, regardless of irregular bank height or channel confinement. This is often defined by a break in the slope of the bank that coincides with the lower limit of permanent (non-aquatic) vegetation. This level has also been referred to as the main-channel (or whole-channel) section by Riggs (1978).

## RESULTS AND DISCUSSION

### HYDROLOGY

**Table 1** lists the location of the Birch Creek gaging sites along with selected characteristics of each reach. The annual streamflow data for these stations are summarized in Appendix A. At two sites, the summer data was collected by the Alaska Division of Mining, Lands and Water, so only the BLM winter discharge measurements are listed. Hydrologically, the Birch Creek basin is characterized by little winter flow, large increases during spring breakup, occasional summer peaks in response to rainfall, and a gradual decline during autumn.

Although the summer flows show a well-defined relationship between sites, the winter streamflow in the lower, unconfined alluvial channels is greater and generally shows more uniformity than in the upper portions of a basin where bedrock often confines the aquifer. The capacity of various types of bedrock to store and transmit water can vary significantly over comparatively short distances, as bedrock aquifers in the Yukon-Tanana uplands primarily conduct ground water within fracture zones (Nelson 1978). A winter flow measurement at one site may have little relationship to other sites in the basin where geological conditions differ. Variability in the basin occurs as flows diminish downstream from the headwaters due to storage as ice. Streamflow may cease altogether if additional groundwater sources (springs) are not available. As flows diminish during the winter, the stream velocity often falls below the threshold values for measuring with mechanical flow meters. Because of these factors, discharge measurements less than about 10



**Figure 2.** Annual Discharge Hydrograph for the Six Principle Gage sites on Birch Creek.

**Table 2.** Monthly Mean and Average Annual Discharge for Birch Creek, 1989 to 1999

| Month                     | *Above<br>Twelvemile<br>Creek | Below<br>Twelvemile<br>Creek | **Above<br>Clums<br>Fork | Above<br>Harrison<br>Creek | Below<br>South Fork | Steese<br>Highway<br>Bridge |
|---------------------------|-------------------------------|------------------------------|--------------------------|----------------------------|---------------------|-----------------------------|
| Jan                       | 2.4 <sup>e</sup>              | 7.2 <sup>e</sup>             | 4.9 <sup>e</sup>         | 13 <sup>e</sup>            | 24 <sup>e</sup>     | 54 <sup>e</sup>             |
| Feb                       | 1.7 <sup>e</sup>              | 5.6 <sup>e</sup>             | 2.5 <sup>e</sup>         | 7.1 <sup>e</sup>           | 13 <sup>e</sup>     | 32 <sup>e</sup>             |
| Mar                       | 1.2 <sup>e</sup>              | 5.2 <sup>e</sup>             | 1.5 <sup>e</sup>         | 4.7 <sup>e</sup>           | 7.5 <sup>e</sup>    | 22 <sup>e</sup>             |
| Apr                       | 19 <sup>e</sup>               | 39 <sup>e</sup>              | 65 <sup>e</sup>          | 119 <sup>e</sup>           | 211 <sup>e</sup>    | 322 <sup>e</sup>            |
| May                       | 189 <sup>e</sup>              | 301 <sup>e</sup>             | 745 <sup>e</sup>         | 1,158 <sup>e</sup>         | 1,929               | 3,861                       |
| Jun                       | 167                           | 235                          | 538                      | 878                        | 1,509               | 2,603                       |
| Jul                       | 70                            | 160                          | 394                      | 576                        | 1,039               | 1,332                       |
| Aug                       | 85                            | 183                          | 510                      | 672                        | 1,172               | 1,569                       |
| Sep                       | 78                            | 171                          | 520                      | 621                        | 1,068               | 1,799                       |
| Oct                       | 31 <sup>e</sup>               | 68 <sup>e</sup>              | 161 <sup>e</sup>         | 274 <sup>e</sup>           | 401 <sup>e</sup>    | 688 <sup>e</sup>            |
| Nov                       | 12 <sup>e</sup>               | 28 <sup>e</sup>              | 51 <sup>e</sup>          | 91 <sup>e</sup>            | 144 <sup>e</sup>    | 230 <sup>e</sup>            |
| Dec                       | 4.3 <sup>e</sup>              | 12 <sup>e</sup>              | 15 <sup>e</sup>          | 29 <sup>e</sup>            | 59 <sup>e</sup>     | 95 <sup>e</sup>             |
| <b>Annual<br/>Average</b> | <b>55</b>                     | <b>101</b>                   | <b>251</b>               | <b>370</b>                 | <b>631</b>          | <b>1,051</b>                |

*Italicized numbers represent discharge data from the Alaska Division of Mining, Lands and Water*

*<sup>e</sup> represents estimated values from discharge measurements at site, other sites on Birch Creek, and USGS Salcha River data).*

*\* 1989–1997*

*\*\* 1990, 1995–99*

**Table 3.** Monthly Mean and Average Annual Discharge Differences for Birch Creek Data from 1989 to 1994 (Kostohrys and Sterin, 1996), Compared to Data from 1989 to 1999

| Month          | Above<br>Twelvemile<br>Creek | Below<br>Twelvemile<br>Creek | Above<br>Clums<br>Fork | Above<br>Harrison<br>Creek | Below<br>South Fork | Steese<br>Highway<br>Bridge |
|----------------|------------------------------|------------------------------|------------------------|----------------------------|---------------------|-----------------------------|
| Jan            | -0.1%                        | 16.1%                        | 35.2%                  | 16.2%                      | 14.6%               | 10.2%                       |
| Feb            | -0.8%                        | 20.4%                        | 38.2%                  | 17.0%                      | 20.4%               | 20.6%                       |
| Mar            | 0.4%                         | 2.9%                         | 37.5%                  | 19.0%                      | 22.4%               | 25.1%                       |
| Apr            | -2.3%                        | 18.2%                        | 12.2%                  | 21.5%                      | 18.3%               | 6.9%                        |
| May            | 2.3%                         | 21.8%                        | 0.0%                   | 21.8%                      | 20.6%               | -1.9%                       |
| Jun            | 5%                           | 8%                           | -14%                   | 7%                         | 3%                  | -3%                         |
| Jul            | -19%                         | -17%                         | -65%                   | -19%                       | -29%                | -7%                         |
| Aug            | -44%                         | -15%                         | -83%                   | -19%                       | -25%                | -14%                        |
| Sep            | -29%                         | -3%                          | -78%                   | -5%                        | -9%                 | -26%                        |
| Oct            | -1%                          | -4%                          | -37%                   | 9%                         | 1%                  | 7%                          |
| Nov            | 5%                           | 5%                           | -12%                   | 17%                        | 11%                 | 14%                         |
| Dec            | 19%                          | 21%                          | 16%                    | 30%                        | 10%                 | 13%                         |
| <b>Average</b> | <b>-6%</b>                   | <b>5%</b>                    | <b>-26%</b>            | <b>6%</b>                  | <b>1%</b>           | <b>-5%</b>                  |



cubic feet per second should be considered estimates. Using this criteria, late winter flows at all the sites except for Birch Creek at the Steese Highway Bridge are considered estimates.

The monthly mean discharge values were updated to include the entire period of record, from 1989 to 2000, at the six sites (**Table 2**). These values are compared to the earlier flow averages, from 1989 to 1994, with the differences listed in **Table 3**. The discharges were reasonably close except for August at the uppermost site on Birch Creek, which might be due to the extreme flooding that occurred in the upper Birch Creek basin during late summer of 1995, and the flows above Clums Fork, which were originally estimated from limited data collected in 1990. The later record, from 1995 to 1999, more nearly reflects the true average at this site. Except in these two instances, the values presented in the original report (Kostohrys and Sterin, 1996) provide reasonable estimates of the streamflow in Birch Creek, given annual and seasonal variability.

The current application for water rights, filed in 2001, was determined for each site on Birch Creek by examination of the cross-sectional properties, such as width, depth, and velocity in each stream reach, not a percentage of the average monthly flows. A change in the average monthly flow on Birch Creek would not necessarily change the requested flow. This differs significantly from the Beaver Creek (Kostohrys 2003) application, where the water requested was a fixed percentage of the estimated average monthly flows (Van Haveran et al., 1987). Any change in the average flows on Beaver Creek would be significant to the request.

**Table 4.** Birch Creek Instantaneous Peak-Flow Frequency from a Log Pearson III Analysis (discharge in cfs)

| <b>Recurrence Interval (yrs)</b> | <b>*Above Twelvemile Creek</b> | <b>Below Twelvemile Creek</b> | <b>Above Clums Fork</b> | <b>Above Harrison Creek</b> | <b>Below South Fork</b> | <b>*Steese Highway Bridge</b> |
|----------------------------------|--------------------------------|-------------------------------|-------------------------|-----------------------------|-------------------------|-------------------------------|
| <b>2</b>                         | 885                            | 1,750                         | 3,750                   | 5,650                       | 9,000                   | 11,800                        |
| <b>5</b>                         | 1,500                          | 2,450                         | 5,300                   | 8,650                       | 14,500                  | 23,600                        |
| <b>10</b>                        | 1,820                          | 3,000                         | 6,050                   | 11,000                      | 19,500                  | 37,100                        |
| <b>25</b>                        | 2,110                          | 3,700                         | 6,650                   | 14,300                      | 28,500                  | 56,400                        |
| <b>50</b>                        | 2,270                          | 4,250                         | 6,970                   | 17,100                      | 37,000                  | 94,000                        |
| <b>100</b>                       | 2,390                          | 4,850                         | 7,200                   | 20,200                      | 48,000                  | 138,000                       |

\*Discharge data from the Alaska Division of Mining, Lands and Water

The peak discharge values, determined from 1) peak water-level elevations at the data logger and crest-stage gages using computer-generated discharges, and 2) minimum discharge values computed from late winter discharge measurements, are listed for each site in **Appendix A**. The flood peak discharges are then analyzed in a Log Pearson Type III frequency distribution, and are summarized in **Tables 5 and 6**. Although gages were able to record peak flows most summers, the presence of ice in the stream during May and September can confound the computation of these flood flows. The formation of overflow icing during the winter as ice freezes to the bottom of the river can fill a channel with thick ice that persists into early June. The process of melting and disintegration of winter ice cover during Spring breakup often results in backwater from ice jamming. Early freeze-up at small streams can also cause backwater during autumn rainstorms. Because of these factors, the peak flows reported in this report should be considered minimum values, since it is likely that higher flows may have occurred during ice-affected periods when no data was recorded.



**Photo 2.** The uniform stream reach at the Harrison Creek crest-stage site allowed for the accurate determination of peak stream flows.

**Table 5.** Birch Creek Tributaries Instantaneous Peak-Flow Frequency from a Log Pearson III Analysis (cfs)

| Recurrence Interval (yrs) | Harrison Creek | Frying Pan Creek | Volcano Creek |
|---------------------------|----------------|------------------|---------------|
| 2                         | 820            | 410              | 54            |
| 5                         | 950            | 680              | 77            |
| 10                        | 990            | 820              | 98            |
| 25                        | 1,020          | 970              | 135           |
| 50                        | 1,040          | 1,060            | 167           |
| 100                       | 1,050          | 1,130            | 210           |

**Appendix B** contains miscellaneous discharge measurements collected intermittently at various sites during the period 1993 to 2001, but not previously reported.

## CHANNEL GEOMETRY

**Appendix C** contains channel geometry plots of selected surveys on Birch Creek and the tributary streams. The sites shown here are the ones where resurveys were conducted in the same stream reach, at or as near as possible to the original surveys. Although most cross sections had only minor changes, the Birch Creek site below Twelvemile Creek and Clums Fork above Volcano Creek showed the most noticeable changes.

Emmett (1972) defines bankfull as the stage at which the channel just begins to overflow onto the flood plain. He notes that to accurately determine the bankfull stage, the stream banks on one

or both sides of the river must be low enough to be overflowed and not be confined by terraces, ridges or bedrock bluffs, conditions seldom met in the rugged upland basins of Birch Creek. As noted earlier, the channel geometry data collected in this study was initially intended to determine peak discharges from flood events, so confinement of the flood flows to a single channel was a priority. The later riparian channel surveys, conducted from 1995 to 2000, were often located more for their proximity to mining or other resources than as sites selected to represent the bankfull channel. Methodologies can be ambiguous—Williams (1979) noted at least 16 ways of determining the bankfull discharge. As for the bankfull discharge representing the 1.5- to 2-year flood, an examination of data on 40 rivers showed that the bankfull discharge had no common recurrence frequency and the 1.5-year flood in most cases did not represent the bankfull discharge (Williams 1979).



**Photo 3.** The crest-stage gage at Frying Pan Creek during high water with remnant aufeis still on the banks.

Riggs (1978) used the bankfull or main channel section to define a relationship to the 10-year flood for rivers in western North America and Alaska. Wahl's (1984) summary stated that the main-channel section and bankfull level are largely the same for perennial streams. Wahl also notes that experience is critical regardless of what methodology is used. Even among trained observers, variations in the field-determined width estimates propagated large errors in the computed bankfull discharges (Wahl 1984). Be that as it may, the bankfull or main-channel characteristics surveyed for the Birch Creek study were not chosen for a rigorous geomorphologic approach or to reflect a given flood interval. Rather, they were chosen to determine the main-channel characteristics that could be used either to assess the impacts of mining runoff or to design channels for placer mining reclamation where no on-site data is available.

**Table 6** contains bankfull channel geometry and discharge data at the surveyed sites. **Table 7** lists the regression relationships for bankfull discharge, width, and depth as a function of drainage area, as well as a calculation example. Although the bankfull discharge and width relationships appear to be reasonably accurate, the bankfull depth relationship to drainage area do not. The variation in the respective bankfull discharges might at first seem large, but the diverse nature of some of the watersheds would imply somewhat disparate runoff characteristics. Although Emmett (1972) was able to determine bankfull channel relationships in Interior Alaska, Childers, et al., (1979), noted large differences in bankfull discharge and peak runoff rates in Northwest Alaska, to the extent that they were unable to determine any clear relationships to drainage basin physiography or climate parameters. More recent work in the National Petroleum Reserve-Alaska has correlated some basin characteristics to bankfull discharge (Kostohrys et al., 2003). A comparison of these bankfull values is listed in Table 8. The regression calculated from the data in this report appears most accurate between drainage basin areas from about 50 to a little over 500 square miles.

**Table 6.** Surveyed Channel Geometry and Calculated Bankfull Discharge

| Site Locality                            | Bankfull Discharge (cfs) | Area (sq ft) | Top Width (ft) | Average Depth (ft) |
|--|--------------------------|--------------|----------------|--------------------|
| <b>Birch Creek:</b>                      |                          |              |                |                    |
| Above Twelvemile Creek                   | 860                      | 177          | 46             | 3.8                |
| Below Twelvemile Creek                   | 1,700                    | 350          | 107            | 3.3                |
| Above Clums Fork                         | 2,710                    | 646          | 192            | 3.4                |
| Above Harrison Creek                     | 4,300                    | 910          | 236            | 3.9                |
| Below South Fork                         | 6,800                    | 1,790        | 252            | 7.1                |
| At Steese Bridge                         | 8,800                    | 1,830        | 315            | 5.8                |
| <b>Tributaries</b>                       |                          |              |                |                    |
| Twelvemile Creek below North Fork*       | 700                      | 162          | 104            | 1.6                |
| Harrington Fork at mouth*                | 1,180                    | 258          | 146            | 1.8                |
| Clums Fork at mouth*                     | 1,800                    | 436          | 117            | 3.7                |
| Harrison Creek at mouth*                 | 1,240                    | 230          | 124            | 1.9                |
| South Fork near mouth*                   | 1,950                    | 611          | 173            | 3.5                |
| Crooked Creek near Central*              | 4,300                    | 604          | 124            | 4.9                |
| Ketchem Creek above Holdem Creek         | 250                      | 34           | 17             | 2.0                |
| Harrison Creek above Bottom Dollar Creek | 900                      | 150          | 69             | 2.2                |
| Frying Pan Creek near mouth              | 350                      | 64           | 28             | 2.3                |
| Volcano Creek near mouth                 | 100                      | 27           | 17             | 1.6                |
| Clums Fork above Volcano Creek           | 755                      | 120          | 49             | 2.4                |
| Clums Fork below Volcano Creek           | 1,100                    | 154          | 71             | 2.2                |
| North Fork Preacher Creek                | 1,350                    | 370          | 120            | 3.1                |
| Preacher Creek below Loper Creek         | 2,510                    | 704          | 234            | 3.0                |

\* Data from Sterin and others, 1998.

**Table 7.** Bankfull Discharge, Width, and Depth Regressions Based on Drainage Area

|   |                          |
|---|--------------------------|
| Bankfull Discharge (cfs) = $58.56 * DA^{0.647}$ | (R <sup>2</sup> = 0.902) |
| Bankfull Width (ft.) = $8.216 * DA^{0.508}$     | (R <sup>2</sup> = 0.906) |
| Bankfull Depth (ft.) = $1.075 * DA^{0.205}$     | (R <sup>2</sup> = 0.591) |

DA: Drainage Area in square miles  
 Example for a stream with a drainage area of: 50 mi<sup>2</sup>  
 Bankfull Discharge =  $58.56 * 50^{0.647} = 736$  cfs  
 Bankfull Width =  $8.216 * 50^{0.508} = 60$  feet

**Table 8.** Comparison of Bankfull Discharge Regressions Based on Drainage Area and the 1.5-Year Recurrence-interval Discharge (cfs)

| Survey Site                              | Drainage Area (mi <sup>2</sup> ) | Field Determined | Birch Creek Regression | Emmett Regression | 1.5-Year Recurrence |
|--|----------------------------------|------------------|------------------------|-------------------|---------------------|
| Birch Creek below Twelvemile Creek       | 156                              | 1,700            | 1,536                  | 1,464             | 1,450               |
| Birch Creek above Clums Fork             | 436                              | 2,710            | 2,987                  | 3,297             | 2,950               |
| Birch Creek above Harrison Creek         | 763                              | 4,300            | 4,290                  | 5,131             | 4,650               |
| Birch Creek below South Fork             | 2,150                            | 6,800            | 8,386                  | 11,630            | 7,450               |
| Harrison Creek above Bottom Dollar Creek | 80                               | 900              | 997                    | 864               | 740                 |
| Frying Pan Creek near mouth              | 21                               | 350              | 420                    | 300               | 300                 |
| Volcano Creek near mouth                 | 6                                | 100              | 187                    | 112               | 48                  |

**RECOMMENDATIONS**

This report includes statistical analysis of streamflow data collected on Birch Creek from 1989 to 2000. The analysis of the data indicates that updating the average monthly discharges on the instream flow reservation filed with the Alaska Department of Natural Resources (DNR) in 2001 may not be warranted. The application for water rights, filed in 2001, was determined for each site on Birch Creek by examination of the cross-sectional properties such as width, depth, and velocity in each stream reach, not as a fixed percentage of the average monthly flows, so any change in the average flow would not necessarily change the requested flow. Since the BLM’s water rights application is already accepted by the DNR and a priority date for the proposed instream flow reservation established, no further action is recommended at this time. The DNR may require additional information or modification of the application during the adjudication process.

Channel-geometry data collected at sites on Birch Creek and several tributaries indicate that significant channel changes have occurred at only a few of the surveyed sites. The cross sections at Birch Creek below Twelvemile Creek and Clums Fork above Volcano Creek showed the most noticeable changes during the study period. Long-term monitoring may be warranted for these reaches, especially those within the wild river corridor, where the changes may impact the resource values for which the wild river was designated. Additional monitoring should continue on those streams with active placer mining to assess channel reclamation. A method of estimating bankfull discharge and channel width is proposed for use in channel reclamation design where no on-site data is available. More data from smaller drainage basins (less than 50 square miles) would improve the accuracy of the regression for smaller stream basins where most placer mining occurs.

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## Appendix A

### DATA SUMMARIES FROM 1995 TO 2000 FOR BIRCH CREEK GAGING SITES

#### BIRCH CREEK ABOVE TWELVEMILE CREEK

(Gage was operated during the summer months  
by Alaska Division of Mining, Lands and Water)

**Table A-1.** Discharge Measurements for Birch Creek above Twelvemile Creek, 1995 to 1997

| Date     | Discharge | Stage | Width                          | Area | Average Velocity | Average Depth |
|----------|-----------|-------|--------------------------------|------|------------------|---------------|
| 03/07/95 | 4.0       | ND    | 11                             | 3.8  | 1.05             | 0.3           |
| 09/15/95 | 187       | 4.58  | 59                             | 67   | 2.79             | 1.1           |
| 11/21/95 | 16        | ND    | 21                             | 10   | 1.60             | 0.5           |
| 03/19/96 | 0         |       | (river frozen solid to bottom) |      |                  |               |
| 11/27/96 | 0.5       | ND    | 6.0                            | 2.4  | 0.21             | 0.4           |
| 03/13/97 | 0         |       | (river frozen solid to bottom) |      |                  |               |

ND: Not Determined

**Table A-2.** Mean Monthly Discharge for Birch Creek above  
Twelvemile Creek, 1995 to 1997

| Month       | 1995      | 1996 | 1997 |
|-------------|-----------|------|------|
| Jan         | 7.0       | 0.1  | 0.1  |
| Feb         | 5.0       | 0.0  | 0.0  |
| Mar         | 3.6       | 0.0  | 0.0  |
| Apr         | 21        | ND   | ND   |
| May         | 167       | ND   | ND   |
| Jun         | 110       | ND   | ND   |
| Jul         | 137       | ND   | ND   |
| Aug         | 240       | ND   | ND   |
| Sep         | 183       | ND   | ND   |
| Oct         | 61        | 4.3  | ND   |
| Nov         | 20        | 0.9  | ND   |
| Dec         | 2.2       | 0.3  | ND   |
| <b>Mean</b> | <b>80</b> |      |      |

*Italicized numbers represent discharge data from Vohden (1995)*

Alaska Division of Mining, Lands and Water gage discontinued 10/01/95

ND: Not Determined

**BIRCH CREEK GAGING SITES** (continued)

**BIRCH CREEK BELOW TWELVEMILE CREEK**

**Table A-3.** Discharge measurement summary for Birch Creek below Twelvemile Creek, 1995 to 1999

| Date     | Discharge | Stage              | Width | Area | Average Velocity | Average Depth |
|----------|-----------|--------------------|-------|------|------------------|---------------|
| 03/07/95 | 12        | ND                 | 32    | 21   | 0.57             | 0.7           |
| 05/30/95 | 195       | 3.48               | 82    | 98   | 1.99             | 1.2           |
| 06/06/95 | 118       | 3.34               | 65    | 56   | 2.11             | 0.9           |
| 07/27/95 | 125       | 3.47               | 74    | 56   | 2.23             | 0.8           |
| 08/29/95 | 195       | 3.76               | 80    | 73   | 2.67             | 0.9           |
| 09/28/95 | 202       | 3.71               | 90    | 97   | 2.08             | 1.1           |
| 11/21/95 | 29        | ND                 | 35    | 33   | 0.88             | 0.9           |
| 03/19/96 | 0         | (frozen to bottom) |       |      |                  |               |
| 05/30/96 | 365       | 4.33               | 93    | 120  | 3.04             | 1.3           |
| 08/01/96 | 42        | 3.06               | 57    | 31   | 1.35             | 0.5           |
| 09/27/96 | 24        | 2.96               | 62    | 37   | 0.65             | 0.6           |
| 11/27/96 | 5.6       | ND                 | 20    | 6.6  | 0.85             | 0.3           |
| 01/29/97 | 4.5       | ND                 | 38    | 9.3  | 0.48             | 0.2           |
| 03/13/97 | 0.1       | ND                 | 7.5   | 1.5  | 0.07             | 0.2           |
| 05/20/97 | 296       | ND                 | 72    | 95   | 3.12             | 1.3           |
| 08/15/97 | 85        | 3.03               | 69    | 54   | 1.57             | 0.8           |
| 09/25/97 | 163       | 3.59               | 79    | 71   | 2.30             | 0.9           |
| 11/25/97 | 28        | ND                 | 27    | 35   | 0.80             | 1.3           |
| 01/28/98 | 3.0       | ND                 | 19    | 5.2  | 0.58             | 0.3           |
| 03/26/98 | 20        | ND                 | 121   | 32   | 0.63             | 0.3           |
| 06/01/98 | 244       | 3.88               | 94    | 92   | 2.65             | 1.0           |
| 07/30/98 | 258       | 4.13               | 93    | 112  | 2.30             | 1.2           |
| 09/30/98 | 157       | 3.72               | 81    | 74   | 2.12             | 0.9           |
| 12/03/98 | 11        | ND                 | 16    | 11   | 1.00             | 0.7           |
| 03/02/99 | 0.1       | ND                 | 12    | 1.6  | 0.06             | 0.1           |
| 07/30/99 | 134       | 3.35               | 81    | 81   | 1.65             | 1.0           |

ND: Not Determined

**Table A-4.** Peak and minimum discharge for Birch Creek below Twelvemile Creek Peak, 1995 to 2000

| Year | Peak Discharge (cfs) | Peak Recurrence Interval (yrs) | Minimum Discharge (cfs) |
|------|----------------------|--------------------------------|-------------------------|
| 1995 | 2,460                | 5.0                            | 12.0                    |
| 1996 | 1,380                | 1.4                            | 0                       |
| 1997 | 950                  | 1.1                            | 0.1                     |
| 1998 | 2,390                | 4.6                            | 3.0                     |
| 1999 | 1,080                | 1.1                            | 0                       |
| 2000 | 1,380                | 1.4                            | ND                      |

ND: Not Determined

**BIRCH CREEK GAGING SITES** (continued)

**Table A-5.** Mean Monthly Discharge for Birch Creek below Twelvemile Creek, 1995 to 1999

|            | 1995 | 1996 | 1997 | 1998 | 1999 |
|------------|------|------|------|------|------|
| <b>Jan</b> | 18   | 0.4  | 4.7  | 4.6  | 1.1  |
| <b>Feb</b> | 14   | 0.1  | 1.1  | 5.3  | 0.2  |
| <b>Mar</b> | 11   | 0.0  | 0.1  | 14   | 0.0  |
| <b>Apr</b> | 52   | 6.6  | 60   | 26   | 7.3  |
| <b>May</b> | 402  | 124  | 173  | 126  | 260  |
| <b>Jun</b> | 289  | 189  | 137  | 254  | 206  |
| <b>Jul</b> | 159  | 140  | 146  | 303  | 167  |
| <b>Aug</b> | 281  | 129  | 141  | 259  | 229  |
| <b>Sep</b> | 349  | 89   | 145  | 132  | 163  |
| <b>Oct</b> | 108  | 15   | 90   | 82   | 57   |
| <b>Nov</b> | 35   | 7.4  | 37   | 23   | 26   |
| <b>Dec</b> | 5.6  | 3.6  | 14   | 6.5  | 12   |

**BIRCH CREEK ABOVE CLUMS FORK**

**Table A-6.** Discharge Measurement Summary for Birch Creek above Clums Fork, 1995 to 2000

| Date            | Discharge | Stage | Width | Area | Average Velocity | Average Depth |
|-----------------|-----------|-------|-------|------|------------------|---------------|
| <b>06/07/95</b> | 332       | 1.80  | 118   | 172  | 1.93             | 1.5           |
| <b>08/01/96</b> | 135       | 1.26  | 104   | 127  | 1.04             | 1.3           |
| <b>09/25/97</b> | 286       | 1.72  | 114   | 127  | 1.04             | 1.3           |
| <b>06/01/98</b> | 735       | 2.27  | 123   | 237  | 3.10             | 1.9           |
| <b>07/30/98</b> | 815       | 2.45  | 114   | 278  | 2.93             | 2.4           |
| <b>09/30/98</b> | 297       | 1.67  | 123   | 156  | 1.90             | 1.3           |
| <b>05/24/99</b> | 482       | 2.23  | 115   | 221  | 2.18             | 1.9           |
| <b>07/30/99</b> | 375       | 1.88  | 122   | 172  | 2.18             | 1.4           |
| <b>09/09/99</b> | 327       | 1.82  | 95    | 203  | 1.61             | 2.1           |
| <b>12/02/99</b> | 27        | ND    | 95    | 68   | 0.40             | 0.7           |
| <b>03/21/00</b> | 0.1       | ND    | 9.0   | 2.0  | 0.05             | 0.2           |

ND: Not Determined

**Table A-7.** Peak and Minimum Discharge for Birch Creek above Clums Fork, 1995 to 2000

| Year        | Peak Discharge (cfs) | Peak and Minimum Discharge Interval (yrs) | Minimum Discharge (cfs) |
|-------------|----------------------|---|-------------------------|
| <b>1995</b> | 6,400                | 16  | 8.6                     |
| <b>1996</b> | 3,770                | 2   | 0.1                     |
| <b>1997</b> | 1,200                | 1.1                                       | 0                       |
| <b>1998</b> | 4,120                | 2.4                                       | 0.4                     |
| <b>1999</b> | 3,850                | 2.1                                       | 0                       |
| <b>2000</b> | 2,930                | 1.5                                       | 0                       |

**BIRCH CREEK GAGING SITES** (continued)

**Table A-8.** Mean Daily Discharge (cfs) for Birch Creek above Clums Fork, 1998

| June        |            | July        |            | August      |            |
|-------------|------------|-------------|------------|-------------|------------|
| Date        | Discharge  | Date        | Discharge  | Date        | Discharge  |
| 1-Jun       | 683        | 1-Jul       | 716        | 1-Aug       | 429        |
| 2-Jun       | 519        | 2-Jul       | 1,211      | 2-Aug       | 305        |
| 3-Jun       | 332        | 3-Jul       | 589        | 3-Aug       | 245        |
| 4-Jun       | 235        | 4-Jul       | 268        | 4-Aug       | 237        |
| 5-Jun       | 252        | 5-Jul       | 196        | 5-Aug       | 227        |
| 6-Jun       | 269        | 6-Jul       | 145        | 6-Aug       | 239        |
| 7-Jun       | 215        | 7-Jul       | 1,083      | 7-Aug       | 312        |
| 8-Jun       | 179        | 8-Jul       | 2,201      | 8-Aug       | 545        |
| 9-Jun       | 157        | 9-Jul       | 1,064      | 9-Aug       | 880        |
| 10-Jun      | 140        | 10-Jul      | 775        | 10-Aug      | 983        |
| 11-Jun      | 135        | 11-Jul      | 931        | 11-Aug      | 852        |
| 12-Jun      | 124        | 12-Jul      | 1,554      | 12-Aug      | 742        |
| 13-Jun      | 110        | 13-Jul      | 1,367      | 13-Aug      | 714        |
| 14-Jun      | 257        | 14-Jul      | 1,053      | 14-Aug      | 611        |
| 15-Jun      | 1,392      | 15-Jul      | 702        | 15-Aug      | 544        |
| 16-Jun      | 3,088      | 16-Jul      | 458        | 16-Aug      | 947        |
| 17-Jun      | 2,173      | 17-Jul      | 367        | 17-Aug      | 1,905      |
| 18-Jun      | 1,576      | 18-Jul      | 351        | 18-Aug      | 1,549      |
| 19-Jun      | 833        | 19-Jul      | 284        | 19-Aug      | 1,194      |
| 20-Jun      | 604        | 20-Jul      | 266        | 20-Aug      | 932        |
| 21-Jun      | 416        | 21-Jul      | 335        | 21-Aug      | 788        |
| 22-Jun      | 381        | 22-Jul      | 329        | 22-Aug      | 905        |
| 23-Jun      | 301        | 23-Jul      | 1,077      | 23-Aug      | 991        |
| 24-Jun      | 224        | 24-Jul      | 860        | 24-Aug      | 832        |
| 25-Jun      | 183        | 25-Jul      | 543        | 25-Aug      | 714        |
| 26-Jun      | 200        | 26-Jul      | 337        | 26-Aug      | 670        |
| 27-Jun      | 212        | 27-Jul      | 268        | 27-Aug      | -          |
| 28-Jun      | 154        | 28-Jul      | 248        | 28-Aug      | -          |
| 29-Jun      | 116        | 29-Jul      | 494        | 29-Aug      | -          |
| 30-Jun      | 190        | 30-Jul      | 811        | 30-Aug      | -          |
|             |            | 31-Jul      | 661        | 31-Aug      | -          |
| <b>Mean</b> | <b>522</b> | <b>Mean</b> | <b>695</b> | <b>Mean</b> | <b>742</b> |

**BIRCH CREEK GAGING SITES** (continued)

**Table A-9.** Mean Daily Discharge (cfs) for Birch Creek above Clums Fork, 1999

| May         |            | June        |            | July        |            | August      |            | September   |            |
|-------------|------------|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
| Date        | Discharge  | Date        | Discharge  | Date        | Discharge  | Date        | Discharge  | Date        | Discharge  |
| 1-May       |            | 1-Jun       | 443        | 1-Jul       | 421        | 1-Aug       | 339        | 1-Sep       | 376        |
| 2-May       |            | 2-Jun       | 416        | 2-Jul       | 386        | 2-Aug       | 338        | 2-Sep       | 380        |
| 3-May       |            | 3-Jun       | 425        | 3-Jul       | 385        | 3-Aug       | 344        | 3-Sep       | 382        |
| 4-May       |            | 4-Jun       | 420        | 4-Jul       | 373        | 4-Aug       | 347        | 4-Sep       | 381        |
| 5-May       |            | 5-Jun       | 411        | 5-Jul       | 358        | 5-Aug       | 336        | 5-Sep       | 398        |
| 6-May       |            | 6-Jun       | 409        | 6-Jul       | 352        | 6-Aug       | 333        | 6-Sep       | 373        |
| 7-May       |            | 7-Jun       | 419        | 7-Jul       | 329        | 7-Aug       | 368        | 7-Sep       | 379        |
| 8-May       |            | 8-Jun       | 424        | 8-Jul       | 358        | 8-Aug       | 2,795      | 8-Sep       | 387        |
| 9-May       |            | 9-Jun       | 421        | 9-Jul       | 355        | 9-Aug       | 1,457      | 9-Sep       | 398        |
| 10-May      |            | 10-Jun      | 424        | 10-Jul      | 361        | 10-Aug      | 2,082      | 10-Sep      |            |
| 11-May      |            | 11-Jun      | 407        | 11-Jul      | 359        | 11-Aug      | 824        | 11-Sep      |            |
| 12-May      |            | 12-Jun      | 410        | 12-Jul      | 358        | 12-Aug      | 500        | 12-Sep      |            |
| 13-May      |            | 13-Jun      | 407        | 13-Jul      | 359        | 13-Aug      | 577        | 13-Sep      |            |
| 14-May      |            | 14-Jun      | 399        | 14-Jul      | 347        | 14-Aug      | 653        | 14-Sep      |            |
| 15-May      |            | 15-Jun      | 384        | 15-Jul      | 358        | 15-Aug      | 470        | 15-Sep      |            |
| 16-May      |            | 16-Jun      | 385        | 16-Jul      | 398        | 16-Aug      | 434        | 16-Sep      |            |
| 17-May      |            | 17-Jun      | 385        | 17-Jul      | 792        | 17-Aug      | 378        | 17-Sep      |            |
| 18-May      |            | 18-Jun      | 678        | 18-Jul      | 605        | 18-Aug      | 356        | 18-Sep      |            |
| 19-May      |            | 19-Jun      | 642        | 19-Jul      | 393        | 19-Aug      | 368        | 19-Sep      |            |
| 20-May      |            | 20-Jun      | 466        | 20-Jul      | 344        | 20-Aug      | 357        | 20-Sep      |            |
| 21-May      |            | 21-Jun      | 408        | 21-Jul      | 341        | 21-Aug      | 373        | 21-Sep      |            |
| 22-May      |            | 22-Jun      | 389        | 22-Jul      | 333        | 22-Aug      | 371        | 22-Sep      |            |
| 23-May      |            | 23-Jun      | 381        | 23-Jul      | 344        | 23-Aug      | 372        | 23-Sep      |            |
| 24-May      | 508        | 24-Jun      | 383        | 24-Jul      | 344        | 24-Aug      | 361        | 24-Sep      |            |
| 25-May      | 580        | 25-Jun      | 392        | 25-Jul      | 355        | 25-Aug      | 357        | 25-Sep      |            |
| 26-May      | 756        | 26-Jun      | 386        | 26-Jul      | 368        | 26-Aug      | 362        | 26-Sep      |            |
| 27-May      | 665        | 27-Jun      | 393        | 27-Jul      | 571        | 27-Aug      | 365        | 27-Sep      |            |
| 28-May      | 756        | 28-Jun      | 1,979      | 28-Jul      | 454        | 28-Aug      | 371        | 28-Sep      |            |
| 29-May      | 886        | 29-Jun      | 1,105      | 29-Jul      | 386        | 29-Aug      | 366        | 29-Sep      |            |
| 30-May      | 649        | 30-Jun      | 580        | 30-Jul      | 366        | 30-Aug      | 371        | 30-Sep      |            |
| 31-May      | 499        |             |            | 31-Jul      | 349        | 31-Aug      | 370        |             |            |
| <b>Mean</b> | <b>662</b> | <b>Mean</b> | <b>506</b> | <b>Mean</b> | <b>394</b> | <b>Mean</b> | <b>571</b> | <b>Mean</b> | <b>384</b> |

**BIRCH CREEK GAGING SITES** (continued)

**Table A-10.** Mean Monthly Discharge for Birch Creek above Clums Fork, 1995 to 1999

|             | 1995       | 1996       | 1997       | 1998       | 1999       |
|-------------|------------|------------|------------|------------|------------|
| <b>Jan</b>  | 21         | 1.8        | 0.2        | 2.1        | 0.9        |
| <b>Feb</b>  | 13         | 0.5        | 0.0        | 0.6        | 0.1        |
| <b>Mar</b>  | 8.6        | 0.1        | 0.0        | 0.4        | 0.0        |
| <b>Apr</b>  | 86         | 8.5        | 90         | 31.8       | 10.1       |
| <b>May</b>  | 1,145      | 256        | 431        | 266        | 662        |
| <b>Jun</b>  | 753        | 431        | 308        | 522        | 506        |
| <b>Jul</b>  | 353        | 298        | 337        | 695        | 394        |
| <b>Aug</b>  | 726        | 270        | 321        | 742        | 571        |
| <b>Sep</b>  | 958        | 171        | 333        | 286        | 384        |
| <b>Oct</b>  | 199        | 37         | 134        | 161        | 112        |
| <b>Nov</b>  | 36         | 4.4        | 51         | 46         | 45         |
| <b>Dec</b>  | 7.0        | 0.5        | 8.1        | 8.8        | 18         |
| <b>Mean</b> | <b>359</b> | <b>123</b> | <b>168</b> | <b>230</b> | <b>225</b> |

**BIRCH CREEK ABOVE HARRISON CREEK**

**Table A-11.** Discharge Measurements summary for Birch Creek above Harrison Creek, 1995 to 1999

| Date     | Discharge | Stage | Width | Area | Average Velocity | Average Depth |
|----------|-----------|-------|-------|------|------------------|---------------|
| 03/08/95 | 19        | ND    | 73    | 41   | 0.46             | 0.6           |
| 06/08/95 | 695       | 3.92  | 208   | 271  | 2.56             | 1.3           |
| 08/29/95 | 1,160     | 4.66  | 212   | 382  | 3.04             | 1.8           |
| 11/30/95 | 27        | ND    | 75    | 85   | 0.32             | 1.1           |
| 03/06/96 | 0.40      | ND    | 25    | 13   | 0.03             | 0.5           |
| 08/01/96 | 261       | 3.34  | 119   | 192  | 1.36             | 1.6           |
| 09/27/96 | 257       | 3.40  | 125   | 196  | 1.31             | 1.6           |
| 11/25/96 | 4.40      | ND    | 66    | 91   | 0.05             | 1.4           |
| 08/15/97 | 401       | 3.67  | 118   | 235  | 1.71             | 2.0           |
| 09/25/97 | 481       | 3.83  | 173   | 229  | 2.10             | 1.3           |
| 11/28/97 | 66        | ND    | 67    | 110  | 0.60             | 1.6           |
| 02/10/98 | 1.0       | ND    | 15    | 5.7  | 0.18             | 0.4           |
| 04/06/98 | 0.6       | ND    | 7.0   | 1.3  | 0.46             | 0.2           |
| 09/30/98 | 541       | 3.90  | 135   | 262  | 2.06             | 1.9           |
| 12/01/98 | 46        | ND    | 54    | 49   | 0.94             | 0.9           |
| 09/09/99 | 646       | 4.09  | 143   | 291  | 2.22             | 2.0           |
| 12/02/99 | 53        | ND    | 92    | 58   | 0.91             | 0.6           |

ND: Not Determined

**BIRCH CREEK GAGING SITES** (continued)

**Table A-12.** Peak and Minimum Discharge for Birch Creek above Harrison Creek, 1995 to 2000

| <b>Date</b> | <b>Discharge (cfs)</b> | <b>Peak Recurrence Interval (yrs)</b> | <b>Minimum Discharge (cfs)</b> |
|-------------|------------------------|---------------------------------------|--------------------------------|
| <b>1995</b> | 7,700                  | 3.7                                   | 19                             |
| <b>1996</b> | 5,090                  | 1.7                                   | 0.4                            |
| <b>1997</b> | 2,370                  | 1.0                                   | 0                              |
| <b>1998</b> | 4,700                  | 1.5                                   | 0.6                            |
| <b>1999</b> | 5,580                  | 1.9                                   | 0                              |
| <b>2000</b> | 4,300                  | 1.4                                   | ND                             |

**Table A-13.** Mean Monthly Discharge for Birch Creek above Harrison Creek, 1995 to 1999

| <b>Month</b> | <b>1995</b> | <b>1996</b> | <b>1997</b> | <b>1998</b> | <b>1999</b> |
|--------------|-------------|-------------|-------------|-------------|-------------|
| <b>Jan</b>   | 41          | 3.6         | 0.3         | 4.2         | 1.9         |
| <b>Feb</b>   | 26          | 1.0         | 0.1         | 0.8         | 0.2         |
| <b>Mar</b>   | 17          | 0.3         | 0.0         | 0.6         | 0.0         |
| <b>Apr</b>   | 175         | 17          | 160         | 61          | 20          |
| <b>May</b>   | 1,677       | 441         | 560         | 395         | 1,085       |
| <b>Jun</b>   | 1,163       | 707         | 428         | 900         | 839         |
| <b>Jul</b>   | 600         | 506         | 460         | 1,111       | 660         |
| <b>Aug</b>   | 1,127       | 462         | 443         | 922         | 941         |
| <b>Sep</b>   | 1,435       | 307         | 456         | 418         | 644         |
| <b>Oct</b>   | 361         | 72          | 255         | 292         | 218         |
| <b>Nov</b>   | 63          | 9           | 99          | 87          | 88          |
| <b>Dec</b>   | 14          | 1.1         | 16          | 17          | 20          |
| <b>Mean</b>  | <b>558</b>  | <b>211</b>  | <b>240</b>  | <b>351</b>  | <b>376</b>  |

**BIRCH CREEK GAGING SITES** (continued)

**BIRCH CREEK BELOW SOUTH FORK**

**Table A-14.** Discharge Measurement Summary for Birch Creek below South Fork, 1995 to 1998

| Date     | Discharge | Stage | Width | Area | Average Velocity | Average Depth |
|----------|-----------|-------|-------|------|------------------|---------------|
| 03/08/95 | 21        | ND    | 30    | 42   | 0.50             | 1.4           |
| 06/08/95 | 1,080     | 1.90  | 300   | 382  | 2.83             | 1.3           |
| 07/27/95 | 1,280     | 2.08  | 300   | 434  | 2.95             | 1.4           |
| 09/28/95 | 1,430     | 2.18  | 315   | 475  | 3.01             | 1.5           |
| 11/30/95 | 60        | ND    | 60    | 97   | 0.62             | 1.6           |
| 03/06/96 | 0.80      | ND    | 29    | 25   | 0.03             | 0.9           |
| 08/01/96 | 381       | 1.16  | 94    | 156  | 2.44             | 1.7           |
| 09/27/96 | 496       | 1.32  | 99    | 177  | 2.80             | 1.8           |
| 11/25/96 | 40        | ND    | 42    | 71   | 0.56             | 1.7           |
| 03/25/97 | 0.80      | ND    | 16    | 15   | 0.05             | 0.9           |
| 05/20/97 | 1,760     | 2.34  | 205   | 818  | 2.15             | 4.0           |
| 08/15/97 | 777       | 1.56  | 107   | 215  | 3.61             | 2.0           |
| 11/28/97 | 125       | ND    | 73    | 103  | 1.21             | 1.4           |
| 02/10/98 | 9.7       | ND    | 38    | 49   | 0.20             | 1.3           |
| 04/06/98 | 5.0       | ND    | 18    | 10   | 0.50             | 0.6           |
| 07/30/98 | 2,906     | 2.76  | 235   | 979  | 2.97             | 4.2           |
| 9/30/98  | 774       | 1.55  | 105   | 208  | 3.72             | 2.0           |
| 12/01/98 | 13        | ND    | 20    | 18   | 0.72             | 0.9           |

ND: Not Determined

**Table A-15.** Birch Creek below South Fork Peak and Minimum Discharge, 1995 to 1999

| Year | Peak Discharge (cfs) | Peak Recurrence Interval (yrs) | Minimum Discharge (cfs) |
|------|----------------------|--------------------------------|-------------------------|
| 1995 | 13,700               | 4.5                            | 21                      |
| 1996 | 6,610                | 1.3                            | 0.8                     |
| 1997 | 5,570                | 1.1                            | 0.8                     |
| 1998 | 8,800                | 1.9                            | 5.0                     |
| 1999 | 9,620                | 2.2                            | 0                       |



**BIRCH CREEK GAGING SITES** (continued)

**Table A-16.** Mean Daily Discharge (cfs) for Birch Creek below South Fork, 1995

| May         |           | June        |              | July        |              | August      |              | September   |              |
|-------------|-----------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|
| Date        | Discharge | Date        | Discharge    | Date        | Discharge    | Date        | Discharge    | Date        | Discharge    |
| 1-May       |           | 1-Jun       | 1,650        | 1-Jul       | 1,441        | 1-Aug       | 835          | 1-Sep       | 4,960        |
| 2-May       |           | 2-Jun       | 1,468        | 2-Jul       | 1,295        | 2-Aug       | 753          | 2-Sep       | 4,679        |
| 3-May       |           | 3-Jun       | 2,039        | 3-Jul       | 1,097        | 3-Aug       | 748          | 3-Sep       | 4,398        |
| 4-May       |           | 4-Jun       | 1,728        | 4-Jul       | 910          | 4-Aug       | 747          | 4-Sep       | 4,117        |
| 5-May       |           | 5-Jun       | 1,336        | 5-Jul       | 762          | 5-Aug       | 811          | 5-Sep       | 3,427        |
| 6-May       |           | 6-Jun       | 1,102        | 6-Jul       | 669          | 6-Aug       | 962          | 6-Sep       | 3,068        |
| 7-May       |           | 7-Jun       | 1,320        | 7-Jul       | 609          | 7-Aug       | 1,073        | 7-Sep       | 2,842        |
| 8-May       |           | 8-Jun       | 1,119        | 8-Jul       | 556          | 8-Aug       | 983          | 8-Sep       | 2,631        |
| 9-May       |           | 9-Jun       | 868          | 9-Jul       | 508          | 9-Aug       | 898          | 9-Sep       | 2,456        |
| 10-May      |           | 10-Jun      | 720          | 10-Jul      | 489          | 10-Aug      | 891          | 10-Sep      | 2,346        |
| 11-May      |           | 11-Jun      | 672          | 11-Jul      | 478          | 11-Aug      | 1,221        | 11-Sep      | 2,387        |
| 12-May      |           | 12-Jun      | 1,204        | 12-Jul      | 967          | 12-Aug      | 1,372        | 12-Sep      | 2,736        |
| 13-May      |           | 13-Jun      | 777          | 13-Jul      | 945          | 13-Aug      | 1,282        | 13-Sep      | 2,486        |
| 14-May      |           | 14-Jun      | 559          | 14-Jul      | 1,076        | 14-Aug      | 1,721        | 14-Sep      | 2,251        |
| 15-May      |           | 15-Jun      | 458          | 15-Jul      | 1,713        | 15-Aug      | 2,414        | 15-Sep      | 2,075        |
| 16-May      |           | 16-Jun      | 513          | 16-Jul      | 2,489        | 16-Aug      | 2,006        | 16-Sep      | 1,924        |
| 17-May      |           | 17-Jun      | 1,514        | 17-Jul      | 1,789        | 17-Aug      | 1,798        | 17-Sep      | 1,790        |
| 18-May      |           | 18-Jun      | 1,471        | 18-Jul      | 1,346        | 18-Aug      | 1,735        | 18-Sep      | 1,683        |
| 19-May      |           | 19-Jun      | 1,073        | 19-Jul      | 1,057        | 19-Aug      | 1,609        | 19-Sep      | 1,588        |
| 20-May      |           | 20-Jun      | 714          | 20-Jul      | 876          | 20-Aug      | 1,592        | 20-Sep      | 1,514        |
| 21-May      |           | 21-Jun      | 768          | 21-Jul      | 765          | 21-Aug      | 2,301        | 21-Sep      | 1,453        |
| 22-May      |           | 22-Jun      | 1,505        | 22-Jul      | 686          | 22-Aug      | 2,523        | 22-Sep      | 1,492        |
| 23-May      |           | 23-Jun      | 1,688        | 23-Jul      | 748          | 23-Aug      | 2,104        | 23-Sep      | 1,329        |
| 24-May      |           | 24-Jun      | 6,715        | 24-Jul      | 766          | 24-Aug      | 1,828        | 24-Sep      | 1,296        |
| 25-May      |           | 25-Jun      | 4,683        | 25-Jul      | 842          | 25-Aug      | 1,921        | 25-Sep      | 1,275        |
| 26-May      |           | 26-Jun      | 6,081        | 26-Jul      | 1,461        | 26-Aug      | 2,156        | 26-Sep      | 1,266        |
| 27-May      |           | 27-Jun      | 6,911        | 27-Jul      | 1,297        | 27-Aug      | 1,971        | 27-Sep      | 1,357        |
| 28-May      |           | 28-Jun      | 3,224        | 28-Jul      | 1,051        | 28-Aug      | 1,901        | 28-Sep      | 1,411        |
| 29-May      |           | 29-Jun      | 2,186        | 29-Jul      | 890          | 29-Aug      | 1,816        | 29-Sep      |              |
| 30-May      | 2,741     | 30-Jun      | 1,648        | 30-Jul      | 779          | 30-Aug      | 6,576        | 30-Sep      |              |
| 31-May      | 1,927     |             |              | 31-Jul      | 736          | 31-Aug      | 7,244        |             |              |
| <b>Mean</b> |           | <b>Mean</b> | <b>1,924</b> | <b>Mean</b> | <b>1,003</b> | <b>Mean</b> | <b>1,864</b> | <b>Mean</b> | <b>2,366</b> |

**BIRCH CREEK GAGING SITES** (continued)

**Table A-17.** Mean Daily Discharge (cfs) for Birch Creek below South Fork, 1996

| May         |           | June        |              | July        |            | August      |            | September   |            |
|-------------|-----------|-------------|--------------|-------------|------------|-------------|------------|-------------|------------|
| Date        | Discharge | Date        | Discharge    | Date        | Discharge  | Date        | Discharge  | Date        | Discharge  |
| 1-May       |           | 1-Jun       | 1,593        | 1-Jul       | 3,770      | 1-Aug       | 364        | 1-Sep       | 786        |
| 2-May       |           | 2-Jun       | 1,716        | 2-Jul       | 3,015      | 2-Aug       | 373        | 2-Sep       | 717        |
| 3-May       |           | 3-Jun       | 1,308        | 3-Jul       | 1,857      | 3-Aug       | 504        | 3-Sep       | 652        |
| 4-May       |           | 4-Jun       | 923          | 4-Jul       | 1,316      | 4-Aug       | 723        | 4-Sep       | 622        |
| 5-May       |           | 5-Jun       | 689          | 5-Jul       | 1,385      | 5-Aug       | 699        | 5-Sep       | 584        |
| 6-May       |           | 6-Jun       | 564          | 6-Jul       | 1,275      | 6-Aug       | 546        | 6-Sep       | 551        |
| 7-May       |           | 7-Jun       | 671          | 7-Jul       | 994        | 7-Aug       | 455        | 7-Sep       | 525        |
| 8-May       |           | 8-Jun       | 738          | 8-Jul       | 731        | 8-Aug       | 404        | 8-Sep       | 499        |
| 9-May       |           | 9-Jun       | 642          | 9-Jul       | 608        | 9-Aug       | 402        | 9-Sep       | 480        |
| 10-May      |           | 10-Jun      | 1,145        | 10-Jul      | 888        | 10-Aug      | 1,523      | 10-Sep      | 465        |
| 11-May      |           | 11-Jun      | 3,842        | 11-Jul      | 1,275      | 11-Aug      | 1,891      | 11-Sep      | 480        |
| 12-May      |           | 12-Jun      | 2,499        | 12-Jul      | 980        | 12-Aug      | 1,337      | 12-Sep      | 504        |
| 13-May      |           | 13-Jun      | 1,776        | 13-Jul      | 731        | 13-Aug      | 1,133      | 13-Sep      | 504        |
| 14-May      |           | 14-Jun      | 1,283        | 14-Jul      | 613        | 14-Aug      | 932        | 14-Sep      | 494        |
| 15-May      |           | 15-Jun      | 1,465        | 15-Jul      | 580        | 15-Aug      | 797        | 15-Sep      | 489        |
| 16-May      |           | 16-Jun      | 1,334        | 16-Jul      | 1,138      | 16-Aug      | 716        | 16-Sep      | 480        |
| 17-May      |           | 17-Jun      | 1,060        | 17-Jul      | 789        | 17-Aug      | 797        | 17-Sep      | 480        |
| 18-May      |           | 18-Jun      | 1,016        | 18-Jul      | 619        | 18-Aug      | 1,790      | 18-Sep      | 455        |
| 19-May      |           | 19-Jun      | 808          | 19-Jul      | 512        | 19-Aug      | 1,381      | 19-Sep      | 514        |
| 20-May      |           | 20-Jun      | 725          | 20-Jul      | 447        | 20-Aug      | 1,071      | 20-Sep      | 711        |
| 21-May      |           | 21-Jun      | 630          | 21-Jul      | 397        | 21-Aug      | 912        | 21-Sep      | 668        |
| 22-May      |           | 22-Jun      | 725          | 22-Jul      | 370        | 22-Aug      | 792        | 22-Sep      | 629        |
| 23-May      |           | 23-Jun      | 707          | 23-Jul      | 340        | 23-Aug      | 711        | 23-Sep      | 578        |
| 24-May      |           | 24-Jun      | 575          | 24-Jul      | 316        | 24-Aug      | 640        | 24-Sep      | 535        |
| 25-May      |           | 25-Jun      | 466          | 25-Jul      | 336        | 25-Aug      | 594        | 25-Sep      | 525        |
| 26-May      |           | 26-Jun      | 401          | 26-Jul      | 419        | 26-Aug      | 611        | 26-Sep      | 520        |
| 27-May      |           | 27-Jun      | 366          | 27-Jul      | 433        | 27-Aug      | 668        | 27-Sep      | 514        |
| 28-May      |           | 28-Jun      | 366          | 28-Jul      | 366        | 28-Aug      | 663        | 28-Sep      |            |
| 29-May      |           | 29-Jun      | 1,069        | 29-Jul      | 329        | 29-Aug      | 617        | 29-Sep      |            |
| 30-May      | 1,907     | 30-Jun      | 5,434        | 30-Jul      | 329        | 30-Aug      | 600        | 30-Sep      |            |
| 31-May      | 1,917     |             |              | 31-Jul      | 383        | 31-Aug      | 657        |             |            |
| <b>Mean</b> |           | <b>Mean</b> | <b>1,218</b> | <b>Mean</b> | <b>888</b> | <b>Mean</b> | <b>816</b> | <b>Mean</b> | <b>554</b> |

**BIRCH CREEK GAGING SITES** (continued)

**Table A-18.** Mean Daily Discharge (cfs) for Birch Creek below South Fork, 1997

| May         |              | June        |            | July        |            | August      |            | September   |            |
|-------------|--------------|-------------|------------|-------------|------------|-------------|------------|-------------|------------|
| Date        | Discharge    | Date        | Discharge  | Date        | Discharge  | Date        | Discharge  | Date        | Discharge  |
| 1-May       |              | 1-Jun       | 1,115      | 1-Jul       | 276        | 1-Aug       | 731        | 1-Sep       | 786        |
| 2-May       |              | 2-Jun       | 843        | 2-Jul       | 258        | 2-Aug       | 652        | 2-Sep       | 766        |
| 3-May       |              | 3-Jun       | 776        | 3-Jul       | 240        | 3-Aug       | 652        | 3-Sep       | 720        |
| 4-May       |              | 4-Jun       | 1,220      | 4-Jul       | 243        | 4-Aug       | 572        | 4-Sep       | 689        |
| 5-May       |              | 5-Jun       | 1,472      | 5-Jul       | 254        | 5-Aug       | 518        | 5-Sep       | 669        |
| 6-May       |              | 6-Jun       | 1,253      | 6-Jul       | 251        | 6-Aug       | 694        | 6-Sep       | 656        |
| 7-May       |              | 7-Jun       | 970        | 7-Jul       | 352        | 7-Aug       | 1,045      | 7-Sep       | 649        |
| 8-May       |              | 8-Jun       | 713        | 8-Jul       | 529        | 8-Aug       | 1,179      | 8-Sep       | 624        |
| 9-May       |              | 9-Jun       | 1,547      | 9-Jul       | 588        | 9-Aug       | 1,194      | 9-Sep       | 600        |
| 10-May      |              | 10-Jun      | 1,879      | 10-Jul      | 467        | 10-Aug      | 1,006      | 10-Sep      | 594        |
| 11-May      |              | 11-Jun      | 1,356      | 11-Jul      | 392        | 11-Aug      | 905        | 11-Sep      | 800        |
| 12-May      |              | 12-Jun      | 977        | 12-Jul      | 1,813      | 12-Aug      | 829        | 12-Sep      | 1,717      |
| 13-May      |              | 13-Jun      | 1,220      | 13-Jul      | 2,007      | 13-Aug      | 782        | 13-Sep      | 1,931      |
| 14-May      |              | 14-Jun      | 1,060      | 14-Jul      | 2,991      | 14-Aug      | 756        | 14-Sep      | 1,887      |
| 15-May      |              | 15-Jun      | 1,130      | 15-Jul      | 1,854      | 15-Aug      | 769        | 15-Sep      | 1,556      |
| 16-May      |              | 16-Jun      | 802        | 16-Jul      | 1,154      | 16-Aug      | 1,112      | 16-Sep      | 1,328      |
| 17-May      |              | 17-Jun      | 870        | 17-Jul      | 843        | 17-Aug      | 1,317      | 17-Sep      | 1,167      |
| 18-May      |              | 18-Jun      | 652        | 18-Jul      | 719        | 18-Aug      | 1,589      | 18-Sep      | 1,056      |
| 19-May      |              | 19-Jun      | 518        | 19-Jul      | 1,763      | 19-Aug      | 1,375      | 19-Sep      | 1,001      |
| 20-May      | 1,793        | 20-Jun      | 518        | 20-Jul      | 1,356      | 20-Aug      | 1,162      | 20-Sep      | 1,044      |
| 21-May      | 1,848        | 21-Jun      | 1,029      | 21-Jul      | 1,529      | 21-Aug      | 1,020      | 21-Sep      | 983        |
| 22-May      | 1,702        | 22-Jun      | 970        | 22-Jul      | 1,634      | 22-Aug      | 909        | 22-Sep      | 916        |
| 23-May      | 1,212        | 23-Jun      | 992        | 23-Jul      | 1,732      | 23-Aug      | 838        | 23-Sep      | 703        |
| 24-May      | 905          | 24-Jun      | 863        | 24-Jul      | 1,782      | 24-Aug      | 831        | 24-Sep      | 797        |
| 25-May      | 985          | 25-Jun      | 694        | 25-Jul      | 1,261      | 25-Aug      | 857        | 25-Sep      | 803        |
| 26-May      | 870          | 26-Jun      | 539        | 26-Jul      | 956        | 26-Aug      | 940        | 26-Sep      |            |
| 27-May      | 802          | 27-Jun      | 442        | 27-Jul      | 802        | 27-Aug      | 1,327      | 27-Sep      |            |
| 28-May      | 856          | 28-Jun      | 378        | 28-Jul      | 713        | 28-Aug      | 1,118      | 28-Sep      |            |
| 29-May      | 956          | 29-Jun      | 340        | 29-Jul      | 640        | 29-Aug      | 972        | 29-Sep      |            |
| 30-May      | 1,270        | 30-Jun      | 303        | 30-Jul      | 577        | 30-Aug      | 891        | 30-Sep      |            |
| 31-May      | 1,427        |             |            | 31-Jul      | 634        | 31-Aug      | 828        |             |            |
| <b>Mean</b> | <b>1,219</b> | <b>Mean</b> | <b>915</b> | <b>Mean</b> | <b>987</b> | <b>Mean</b> | <b>947</b> | <b>Mean</b> | <b>978</b> |

**BIRCH CREEK GAGING SITES** (continued)

**Table A-19.** Mean Daily Discharge (cfs) for Birch Creek below South Fork, 1998

| June        |              | July        |              | August      |              | September   |            |
|-------------|--------------|-------------|--------------|-------------|--------------|-------------|------------|
| Date        | Discharge    | Date        | Discharge    | Date        | Discharge    | Date        | Discharge  |
| 1-Jun       | 1,598        | 1-Jul       | 2,973        | 1-Aug       | 1,669        | 1-Sep       | 1,286      |
| 2-Jun       | 1,161        | 2-Jul       | 4,054        | 2-Aug       | 1,383        | 2-Sep       | 1,215      |
| 3-Jun       | 873          | 3-Jul       | 2,709        | 3-Aug       | 1,215        | 3-Sep       | 1,174      |
| 4-Jun       | 712          | 4-Jul       | 1,614        | 4-Aug       | 1,117        | 4-Sep       | 1,105      |
| 5-Jun       | 706          | 5-Jul       | 1,579        | 5-Aug       | 1,072        | 5-Sep       | 1,016      |
| 6-Jun       | 829          | 6-Jul       | 1,257        | 6-Aug       | 1,206        | 6-Sep       | 953        |
| 7-Jun       | 767          | 7-Jul       | 3,855        | 7-Aug       | 1,845        | 7-Sep       | 957        |
| 8-Jun       | 717          | 8-Jul       | 5,656        | 8-Aug       | 2,700        | 8-Sep       | 941        |
| 9-Jun       | 682          | 9-Jul       | 3,335        | 9-Aug       | 3,258        | 9-Sep       | 904        |
| 10-Jun      | 664          | 10-Jul      | 2,830        | 10-Aug      | 3,358        | 10-Sep      | 847        |
| 11-Jun      | 673          | 11-Jul      | 3,649        | 11-Aug      | 2,952        | 11-Sep      | 797        |
| 12-Jun      | 700          | 12-Jul      | 4,437        | 12-Aug      | 2,404        | 12-Sep      | 739        |
| 13-Jun      | 703          | 13-Jul      | 4,930        | 13-Aug      | 1,856        | 13-Sep      | 728        |
| 14-Jun      | 785          | 14-Jul      | 3,588        | 14-Aug      | 1,642        | 14-Sep      | 740        |
| 15-Jun      | 2,068        | 15-Jul      | 2,395        | 15-Aug      | 1,479        | 15-Sep      | 711        |
| 16-Jun      | 6,243        | 16-Jul      | 1,535        | 16-Aug      | 1,727        | 16-Sep      | 717        |
| 17-Jun      | 6,006        | 17-Jul      | 1,265        | 17-Aug      | 3,407        | 17-Sep      | 775        |
| 18-Jun      | 4,838        | 18-Jul      | 1,227        | 18-Aug      | 3,361        | 18-Sep      | 787        |
| 19-Jun      | 3,278        | 19-Jul      | 1,123        | 19-Aug      | 2,767        | 19-Sep      | 747        |
| 20-Jun      | 2,718        | 20-Jul      | 1,123        | 20-Aug      | 2,099        | 20-Sep      | 774        |
| 21-Jun      | 1,941        | 21-Jul      | 1,162        | 21-Aug      | 1,659        | 21-Sep      | 774        |
| 22-Jun      | 3,319        | 22-Jul      | 1,249        | 22-Aug      | 1,675        | 22-Sep      | 770        |
| 23-Jun      | 3,045        | 23-Jul      | 2,405        | 23-Aug      | 1,999        | 23-Sep      | 770        |
| 24-Jun      | 2,217        | 24-Jul      | 2,529        | 24-Aug      | 1,734        | 24-Sep      | 770        |
| 25-Jun      | 1,563        | 25-Jul      | 1,967        | 25-Aug      | 1,566        | 25-Sep      | 774        |
| 26-Jun      | 3,013        | 26-Jul      | 1,509        | 26-Aug      | 1,606        | 26-Sep      | 790        |
| 27-Jun      | 2,416        | 27-Jul      | 1,240        | 27-Aug      | 2,378        | 27-Sep      | 811        |
| 28-Jun      | 1,518        | 28-Jul      | 1,188        | 28-Aug      | 2,113        | 28-Sep      | 793        |
| 29-Jun      | 1,348        | 29-Jul      | 1,788        | 29-Aug      | 1,724        | 29-Sep      | 783        |
| 30-Jun      | 1,215        | 30-Jul      | 2,873        | 30-Aug      | 1,534        | 30-Sep      | 774        |
|             |              | 31-Jul      | 2,486        | 31-Aug      | 1,369        |             |            |
| <b>Mean</b> | <b>1,944</b> | <b>Mean</b> | <b>2,436</b> | <b>Mean</b> | <b>1,996</b> | <b>Mean</b> | <b>857</b> |

**BIRCH CREEK GAGING SITES** (continued)

**Table A-20.** Mean Monthly Discharge for Birch Creek below South Fork, 1995 to 1999

| Month | 1995  | 1996  | 1997  | 1998  | 1999  |
|-------|-------|-------|-------|-------|-------|
| Jan   | 55    | 7.6   | 7.5   | 23    | 8.1   |
| Feb   | 31    | 2.0   | 2.8   | 9.2   | 1.5   |
| Mar   | 18    | 0.5   | 1.1   | 6.5   | 0.3   |
| Apr   | 299   | 36    | 319   | 110   | 54    |
| May   | 2,757 | 781   | 1,219 | 806   | 1,570 |
| Jun   | 1,924 | 1,218 | 915   | 1,944 | 1,264 |
| Jul   | 1,003 | 888   | 987   | 2,436 | 1,033 |
| Aug   | 1,864 | 816   | 947   | 1,996 | 1,393 |
| Sep   | 2,366 | 554   | 978   | 857   | 1,012 |
| Oct   | 593   | 225   | 437   | 341   | 377   |
| Nov   | 128   | 61    | 182   | 68    | 180   |
| Dec   | 30    | 21    | 68    | 49    | 87    |
| Mean  | 922   | 384   | 505   | 721   | 581   |

**BIRCH CREEK AT STEESE HIGHWAY BRIDGE**

(Gage was operated during the summer months by Alaska Division of Mining, Lands, and Water)

**Table A-21.** Discharge Measurements for Birch Creek at Steese Highway Bridge, 1995 to 1999

| Date     | Discharge | Stage | Width | Area | Average Velocity | Average Depth |
|----------|-----------|-------|-------|------|------------------|---------------|
| 11/30/95 | 117       | ND    | 180   | 458  | 0.26             | 2.5           |
| 3/19/96  | 11        | ND    | 32    | 14   | 0.79             | 0.4           |
| 11/25/96 | 78        | ND    | 168   | 145  | 0.54             | 0.9           |
| 3/25/97  | 10        | ND    | 24    | 14   | 0.71             | 0.6           |
| 2/10/98  | 24        | ND    | 125   | 115  | 0.21             | 0.9           |
| 1/15/99  | 33        | ND    | 65    | 34   | 0.97             | 0.5           |
| 3/4/99   | 0.3       | ND    | 7.0   | 4.0  | 0.08             | 0.6           |

ND: Not Determined

**BIRCH CREEK GAGING SITES** (continued)

**Table A-22.** Mean Monthly Discharge for Birch Creek at Steese Highway Bridge, from 1989 to 1999

| <b>Month</b> | <b>1995</b>  | <b>1996</b> | <b>1997</b> | <b>1998</b> | <b>1999</b> |
|--------------|--------------|-------------|-------------|-------------|-------------|
| <b>Jan</b>   | 82           | 43          | 32          | 50          | 32          |
| <b>Feb</b>   | 54           | 23          | 19          | 21          | 1.7         |
| <b>Mar</b>   | 36           | 12          | 12          | 12          | 0.3         |
| <b>Apr</b>   | 467          | 57          | ND          | ND          | ND          |
| <b>May</b>   | 4,192        | ND          | ND          | ND          | ND          |
| <b>Jun</b>   | <i>3,090</i> | ND          | ND          | ND          | ND          |
| <b>Jul</b>   | <i>1,860</i> | ND          | ND          | ND          | ND          |
| <b>Aug</b>   | <i>2,680</i> | ND          | ND          | ND          | ND          |
| <b>Sep</b>   | <i>3,990</i> | ND          | ND          | ND          | ND          |
| <b>Oct</b>   | 1,177        | 376         | ND          | ND          | ND          |
| <b>Nov</b>   | 250          | 115         | ND          | ND          | ND          |
| <b>Dec</b>   | 84           | 55          | ND          | ND          | ND          |
| <b>Mean</b>  | 1,497        |             |             |             |             |

*Italicized numbers represent discharge data from Vohden (1995), Alaska DMLW.*

Gage discontinued 10/01/95

ND: Not Determined

## Appendix B

### DISCHARGE SUMMARIES FOR PEAK FLOW AND MISCELLANEOUS SURVEY SITES

**Table B-1.** Discharge Measurements for Frying Pan Creek near the Mouth, 1995 to 2000

| Date     | Stage (ft) | Discharge (cfs) | Width (ft) | Area (ft) | Average Velocity (fps) | Average Depth (ft) |
|----------|------------|-----------------|------------|-----------|------------------------|--------------------|
| 08/29/95 | 1.20       | 33              | 22         | 18        | 1.83                   | 0.8                |
| 09/28/95 | 1.05       | 21              | 31         | 20        | 1.05                   | 0.7                |
| 05/30/96 | 1.09       | 19              | 20         | 18        | 1.06                   | 0.9                |
| 08/01/96 | 0.50       | 3.7             | 17         | 7.1       | 0.52                   | 0.4                |
| 09/27/96 | 0.45       | 4.0             | 16         | 5.9       | 0.68                   | 0.4                |
| 08/15/97 | 0.80       | 21              | 14         | 9.3       | 2.26                   | 0.7                |
| 09/25/97 | 0.95       | 32              | 21         | 14        | 2.29                   | 0.7                |
| 07/30/99 | 0.88       | 12              | 24         | 13        | 0.92                   | 0.6                |
| 06/01/00 | 1.57       | 74              | 33         | 33        | 2.24                   | 1.0                |
| 09/04/00 | 1.00       | 20              | 31         | 19        | 1.05                   | 0.6                |

**Table B-2.** Peak Discharge for Frying Pan Creek near the Mouth, 1995 to 2002

| Date | Discharge (cfs) | Recurrence (yrs) |
|------|-----------------|------------------|
| 1995 | 800             | 9.0              |
| 1996 | 407             | 2.0              |
| 1997 | 82              | 1.0              |
| 1998 | 650             | 4.5              |
| 1999 | 670             | 4.9              |
| 2000 | 276             | 1.4              |
| 2001 | 217             | 1.3              |
| 2002 | 383             | 1.9              |

**Table B-3.** Discharge Measurement Summary for Volcano Creek near the Mouth, 1997 to 2000

| Date    | Stage (ft) | Discharge (cfs) | Width (ft) | Area (ft) | Average Velocity (fps) | Average Depth (ft) |
|---------|------------|-----------------|------------|-----------|------------------------|--------------------|
| 6/1/97* | 1.84       | 40              | 23         | 14        | 2.86                   | 0.6                |
| 6/12/97 | 0.79       | 6.3             | 10         | 5.7       | 1.11                   | 0.6                |
| 8/24/98 | 1.17       | 10.0            | 10         | 3.5       | 2.86                   | 0.4                |
| 7/7/99  | 0.66       | 1.8             | 9.5        | 3.1       | 0.57                   | 0.3                |
| 7/18/00 | ND         | 8.2             | 6.0        | 3.7       | 2.22                   | 0.6                |
| 9/4/00  | 0.96       | 7.8             | 9.5        | 4.9       | 1.59                   | 0.5                |

\*Slope-Area Indirect discharge computation  
ND: Not Determined

**PEAK FLOW AND MISCELLANEOUS SURVEY SITES** (continued)

**Table B-4.** Peak Discharge for Volcano Creek near the Mouth,  
 1997 to 2002

| Date | Discharge (cfs) | Recurrence Interval (yrs) |
|------|-----------------|---------------------------|
| 1997 | 40              | 1.1                       |
| 1998 | 120             | 18                        |
| 1999 | 60              | 2.6                       |
| 2000 | 50              | 1.6                       |
| 2001 | 52              | 1.8                       |
| 2002 | 60              | 2.6                       |

**Table B-5.** Discharge Measurement Summary for Harrison Creek above Bottom Dollar Creek,  
 1996 to 2000

| Date      | Stage (ft) | Discharge (cfs) | Width (ft) | Area (ft) | Average Velocity (fps) | Average Depth (ft) |
|-----------|------------|-----------------|------------|-----------|------------------------|--------------------|
| 09/05/96  | 1.48       | 40              | 36         | 33        | 1.21                   | 0.9                |
| 09/09/97  | 1.42       | 43              | 38         | 30        | 1.44                   | 0.8                |
| 08/07/98* | 3.58       | 974             | 69         | 156       | 6.24                   | 2.3                |
| 08/12/98  | 2.01       | 91              | 43         | 51        | 1.79                   | 1.2                |
| 09/09/99  | 1.75       | 67              | 42         | 51        | 1.32                   | 1.2                |
| 09/04/00  | 1.94       | 104             | 46         | 57        | 1.80                   | 1.2                |

\* Slope-Area Indirect discharge computation

**Table B-6.** Peak Discharge for Harrison Creek above Bottom Dollar Creek,  
 1996 to 2000

| Date | Discharge (cfs) | Recurrence Interval (yrs) |
|------|-----------------|---------------------------|
| 1996 | 778             | 1.7                       |
| 1997 | 511             | 1.1                       |
| 1998 | 974             | 7.1                       |
| 1999 | 887             | 2.9                       |
| 2000 | 806             | 1.9                       |



**PEAK FLOW AND MISCELLANEOUS SURVEY SITES** (continued)

**Table B-7.** Discharge Measurements at Miscellaneous Sites, 1993 to 1999

| Site                                     | Date      | Stage (ft) | Discharge (cfs) | Width (ft) | Area (ft <sup>2</sup> ) | Average Velocity (fps) | Average Depth (ft) |
|--|-----------|------------|-----------------|------------|-------------------------|------------------------|--------------------|
| <b>Ketchem Creek above Holdem Creek</b>  | 06/11/96* | 3.30       | 250             | 17         | 34                      | 7.29                   | 2.0                |
| <b>Ketchem Creek above Holdem Creek</b>  | 09/04/96  | 0.90       | 1.6             | 5.2        | 1.6                     | 1.00                   | 0.3                |
| <b>Clums Fork above Volcano Creek</b>    | 08/26/98  | 3.05       | 95              | 37         | 38                      | 2.50                   | 1.0                |
| <b>Clums Fork above Volcano Creek</b>    | 07/08/99  | 1.90       | 11              | 29         | 15                      | 0.71                   | 0.5                |
| <b>Clums Fork below Volcano Creek</b>    | 08/26/98  | 3.34       | 93              | 48         | 33                      | 2.84                   | 0.7                |
| <b>Clums Fork below Volcano Creek</b>    | 07/08/99  | 2.83       | 11              | 31         | 14                      | 0.79                   | 0.5                |
| <b>North Fork Preacher Creek</b>         | 06/20/95  | 2.30       | 127             | 48         | 63                      | 2.02                   | 1.3                |
| <b>Preacher Creek below Loper Creek</b>  | 08/16/93  | 2.00       | 156             | 114        | 119                     | 1.31                   | 1.0                |
| <b>Preacher Creek below Loper Creek</b>  | 11/29/94  | ND (Ice)   | 32              | 76         | 112                     | 0.29                   | 1.5                |
| <b>Preacher Creek below Loper Creek</b>  | 06/20/95  | 2.64       | 438             | 142        | 241                     | 1.82                   | 1.7                |
| <b>Twelvemile Creek below North Fork</b> | 08/10/95  | 1.24       | 27              | 48         | 30                      | 0.90                   | 0.6                |

\* Slope-area indirect discharge computation

ND: Not Determined

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## Appendix C: Channel Geometry

### RESURVEYS OF CROSS SECTIONS AT SITES ON BIRCH CREEK AND TRIBUTARIES

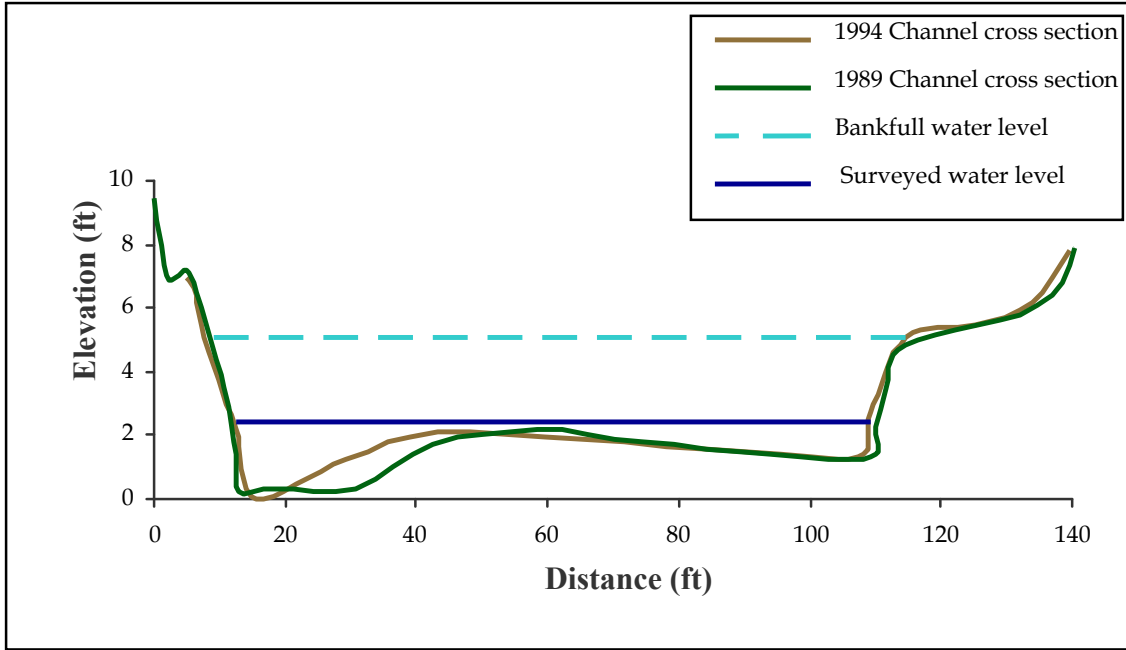


Figure C-1. Bankfull Channel Cross Section for Birch Creek below Twelvemile Creek

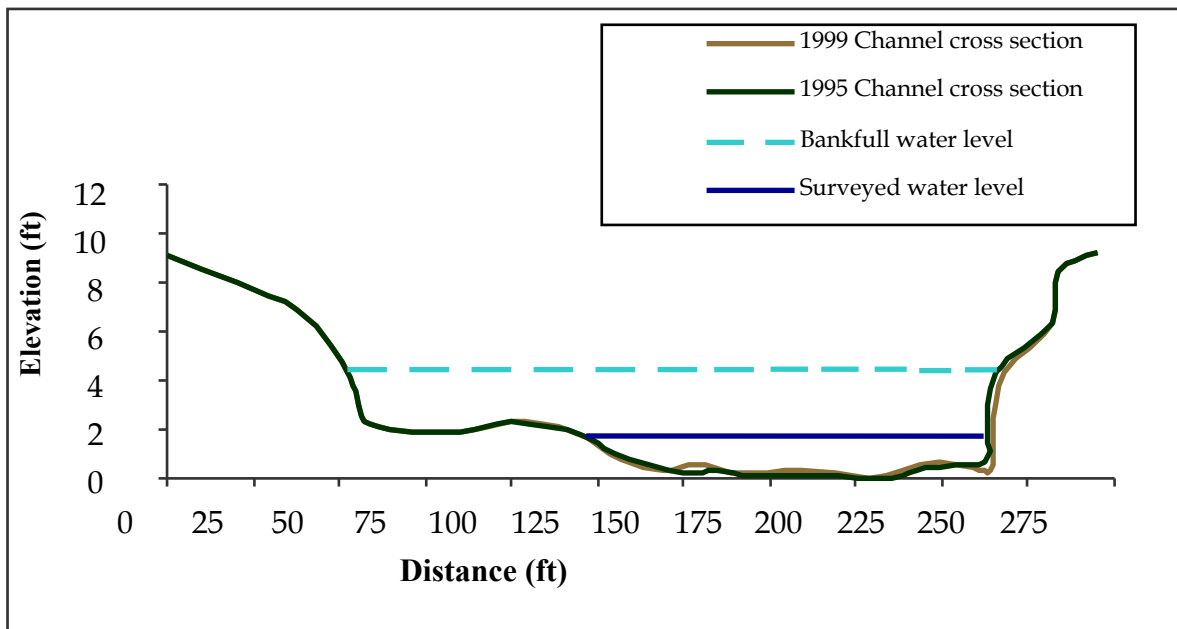


Figure C-2. Bankfull Channel Cross Section for Birch Creek above Clums Fork

RESURVEYS ON BIRCH CREEK AND TRIBUTARIES (continued)

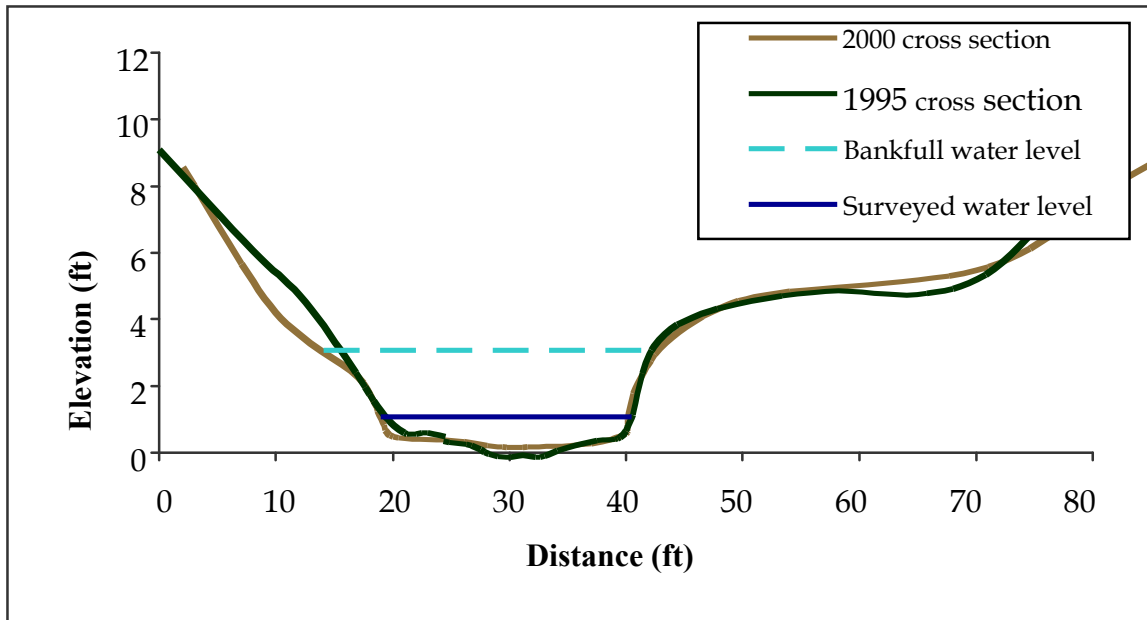


Figure C-3. Bankfull Channel Cross Section for Frying Pan Creek near the Mouth

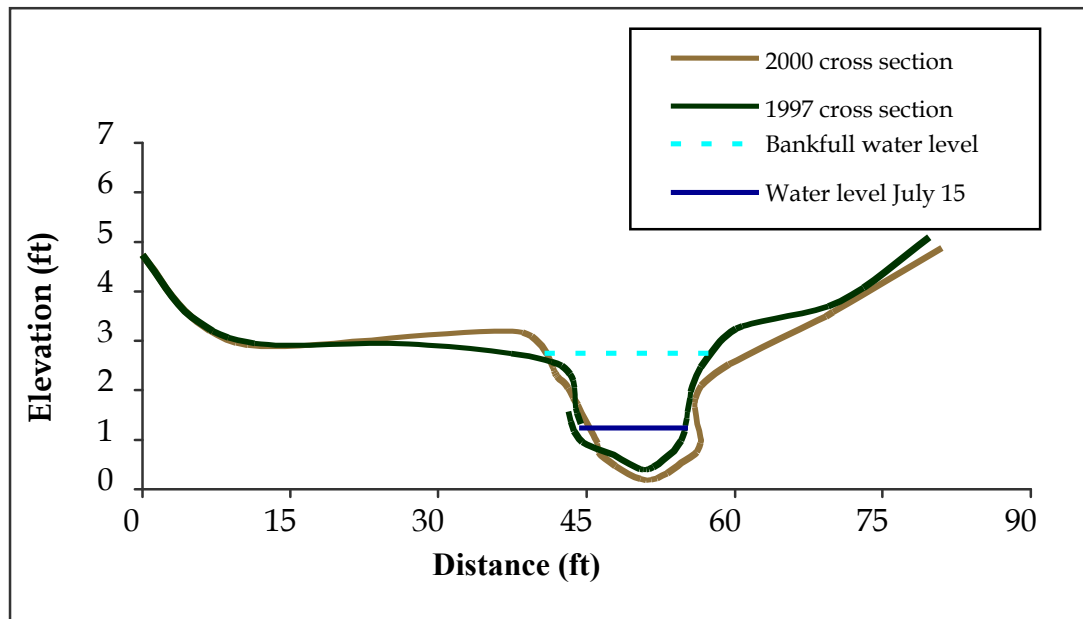
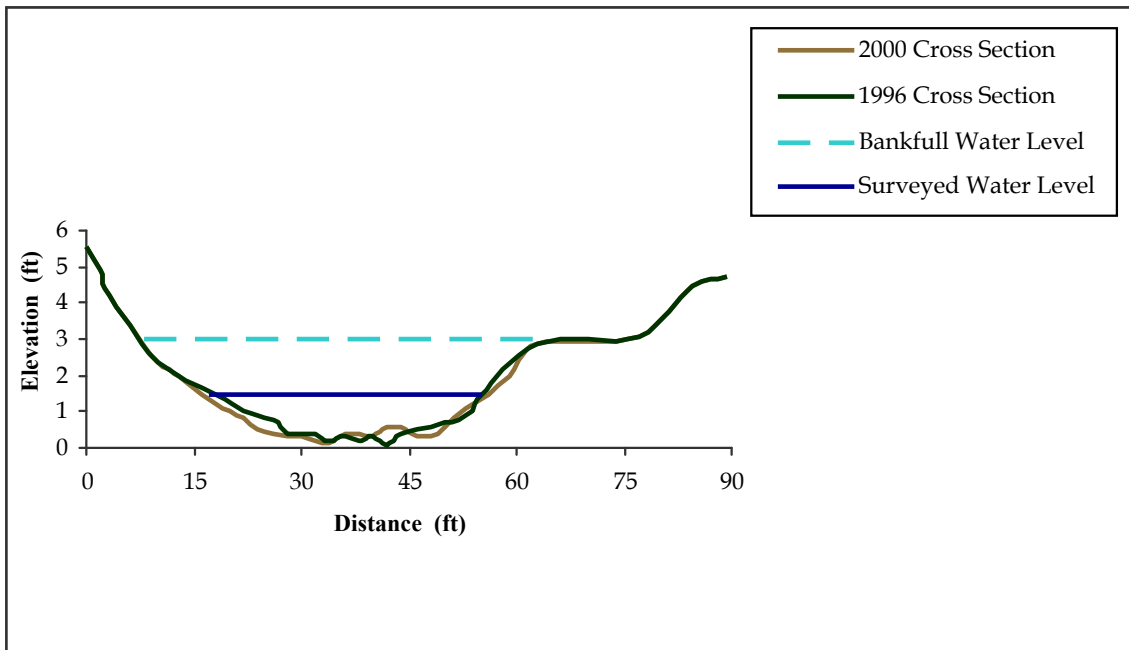
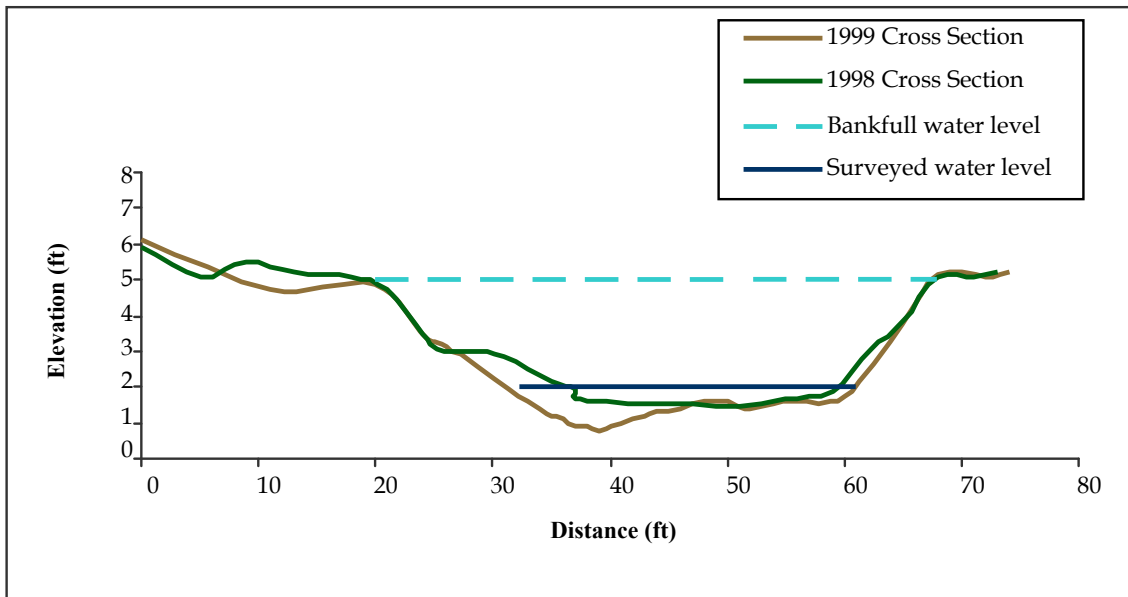


Figure C-4. Bankfull Channel Cross Section for Volcano Creek near the Mouth

**RESURVEYS ON BIRCH CREEK AND TRIBUTARIES (continued)**



**Figure C-5.** Bankfull Channel Cross Section for Harrison Creek above Bottom Dollar Creek



**Figure C-6.** Bankfull Channel Cross Section for Clums Fork above Volcano Creek

RESURVEYS ON BIRCH CREEK AND TRIBUTARIES (continued)

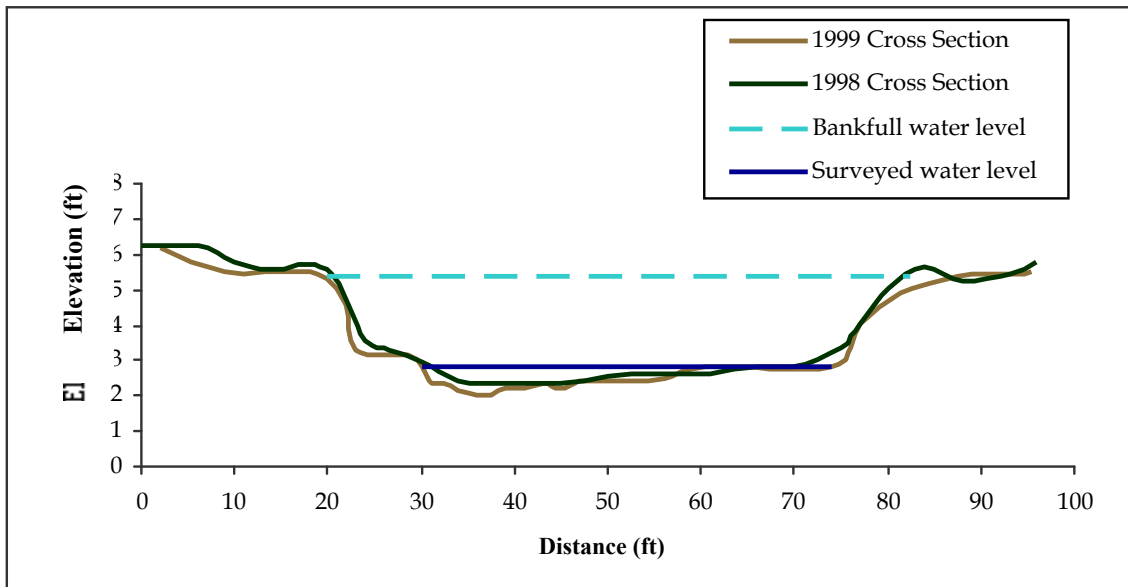


Figure C-7. Bankfull Channel Cross Section for Clums Fork below Volcano Creek