TECHNICAL MEMORANDUM

HYDROLOGY AND POWER STUDIES TO DATE

15 APRIL 2011

ALASKA RAILBELT LARGE HYDRO ENGINEERING SERVICES

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PREPARED FOR: ALASKA ENERGY AUTHORITY

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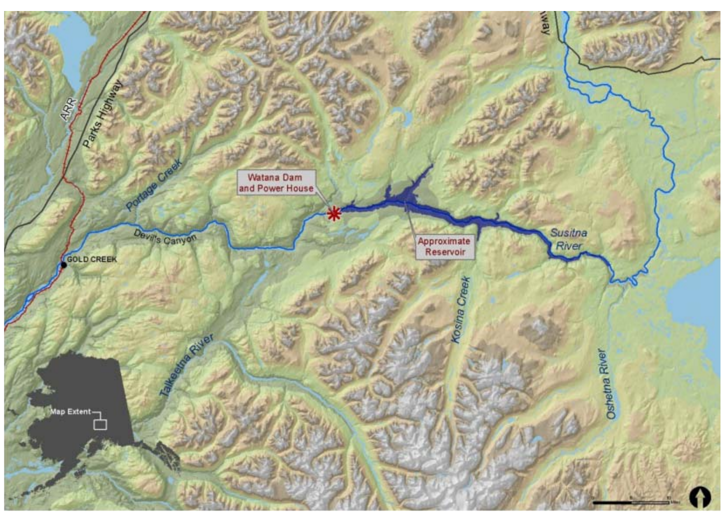

TECHNICAL MEMORANDUM ON HYDROLOGY AND POWER STUDIES TO DATE

The purpose of this technical memorandum is to summarize progress on hydrology and reservoir operation and power studies at the current early stage of studies. Results presented herein are preliminary.

HYDROLOGY

Hydrologic data is being gathered for two general purposes, first for presentation in the Pre-Application Document (PAD), and second for developing a long-term record of reservoir inflows and flood frequency data at the Watana dam site. Table 1 summarizes the available USGS flow data in the Susitna watershed. The two most useful USGS gaging stations for developing flow at the Watana dam site are the downstream gage at Gold Creek (6,160 square miles drainage area) and the upstream gage at Cantwell (4,140 square miles drainage area). For comparison, the drainage area at the Watana dam site is 5,180 square miles.

Table 1: USGS Streamflow Gages in the Susitna Watershed

USGS Gage Number	Gage Name	Drainage Area (sq.mi)	Latitude	Longitude	Gage Datum (feet)	Available Period of Record
15290000	Little Susitna River near Palmer	62	61°42'37"	149°13'47"	916.6	63 years: 1948 - 2011
15291000	Susitna River near Denali	950	63°06'14"	147°30'57"	2440	27 years: 1957 - 1976; 1978 - 1986
15291500	Susitna River near Cantwell	4,140	62°41'55"	147°32'42"	1900	17 years: 1961 - 1972; 1980 - 1986
15292000	Susitna River at Gold Creek	6,160	62°46'04"	149°41'28"	676.5	57 years: 1949 - 1996; 2001 - 2011
15292400	Chulitna River	2,570	62°33'31"	150°14'02"	520	19 years: 1958 - 1972; 1980 - 1986
15292700	Talkeetna River near Talkeetna	1,996	62°20'49"	150°01'01"	400	39 years: 1964 - 1972; 1980 - 2011
15292780	Susitna River at Sunshine	11,100	62°10'42"	150°10'30"	270	5 years: 1981 - 1986
15292800	Montana Creek near Montana	164	62°06'19"	150°03'27"	250	4 years: 2005 - 2006; 2008 - 2011
15294005	Willow Creek Near Willow	166	61°46'51"	149°53'04"	350	25 years: 1978 - 1993; 2001 - 2011
15294010	Deception Creak near Willow	48	61°44'52"	149°56'14"	250	7 years: 1978 - 1985
15294100	Deshka River near Willow	591	61°46'05"	150°20'13"	80	21 years: 1978 - 1986; 1988 - 2001
15294300	Skwentna River near Skwentna	2,250	61°52'23"	151°22'01"	200	23 years: 1959 - 1982
15294345	Yentna River near Susitna Station	6,180	61°41'55"	150°39'02"	80	6 years: 1980 - 1986
15294350	Susitna River at Susitna Station	19,400	61°32'41"	150°30'45"	40	19 years: 1974 - 1993

Periods of concurrent flow data can be used for fill-in and extension of data sets, or for developing data at ungaged sites. Figure 1 shows the chronological availability of USGS flow data in the Susitna watershed. For example, the 17 years of Cantwell data is concurrent with the Gold Creek data, which provides a useful flow record both upstream and downstream from the Watana dam site. Figure 1 also shows an active period of flow gaging in the early 1980s.

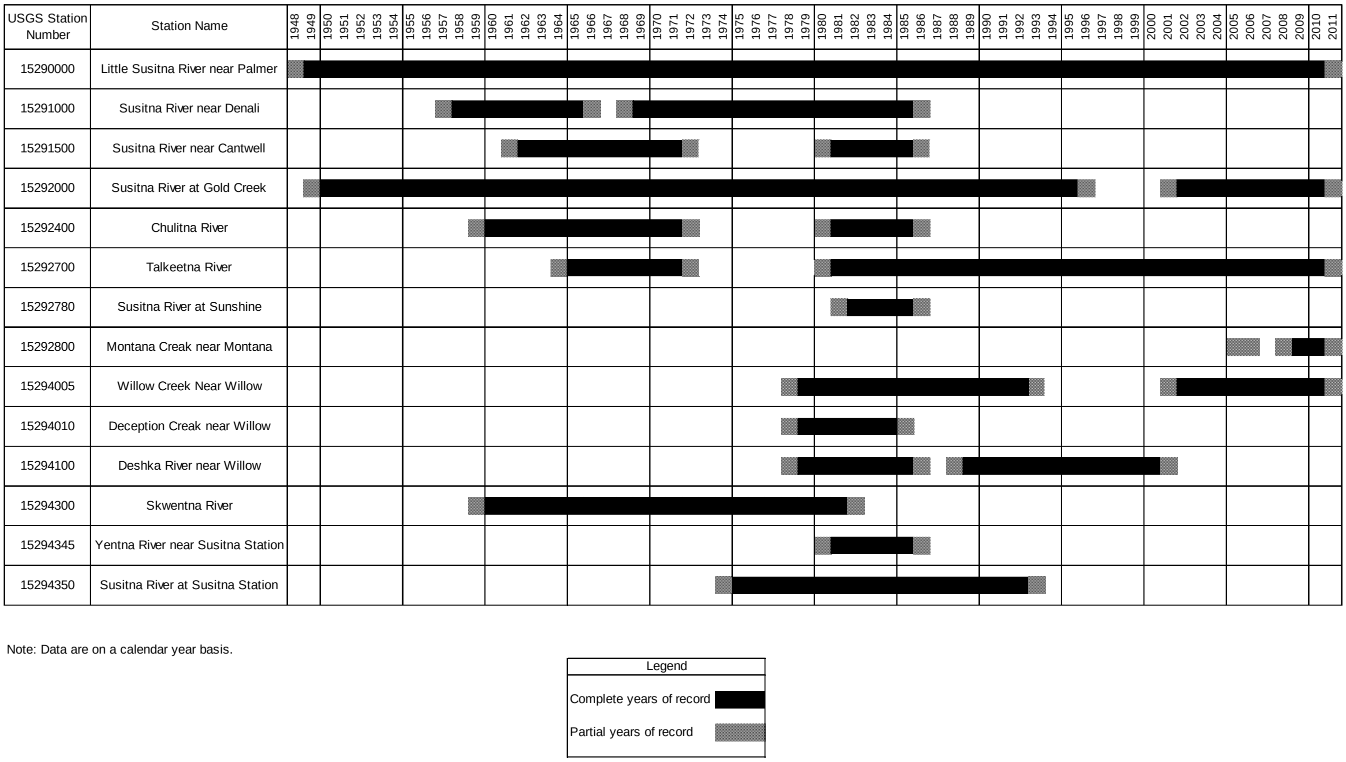

Figure 1: Susitna Watershed USGS Flow Data – Chronological Availability

Susitna River flow is highly seasonal as shown on Figure 2, which is based on daily flows at the USGS gage at Gold Creek. Figure 2 exhibits the characteristic shape of streamflow for many Alaskan rivers, but the flow characteristics will change at least somewhat at different locations on a river and among different rivers. Numerous tables and plots are currently in preparation for the PAD to display the flow characteristics of the Susitna watershed.

By subtracting the monthly recorded Cantwell gage flows from the Gold Creek gage flows yields a 17 year data set of flow between gages that includes the Watana dam site. Analysis of this flow between gages data set has shown that it has monthly flow characteristics that are somewhat different from the Gold Creek gage, primarily due to the timing of snowmelt at different elevations and a slightly different runoff per unit area. A long-term record of reservoir inflows at the ungaged Watana dam site must be developed for use in the reservoir operation and power studies. It is expected that the Gold Creek flows will be adjusted to the Watana dam site using monthly factors derived based on a comparison of the concurrent flow at Gold Creek and the runoff between gages. The result will be a 55 year period (excluding the recent USGS provisional flow data) of daily inflows to the proposed Watana reservoir.

We understand that two or three years of flow data was gathered at or near the Watana dam site by R&M in the early 1980s. Efforts are being made to retrieve this flow data, which will then be evaluated for accuracy and utility in improving the estimate of long-term flows at Watana.

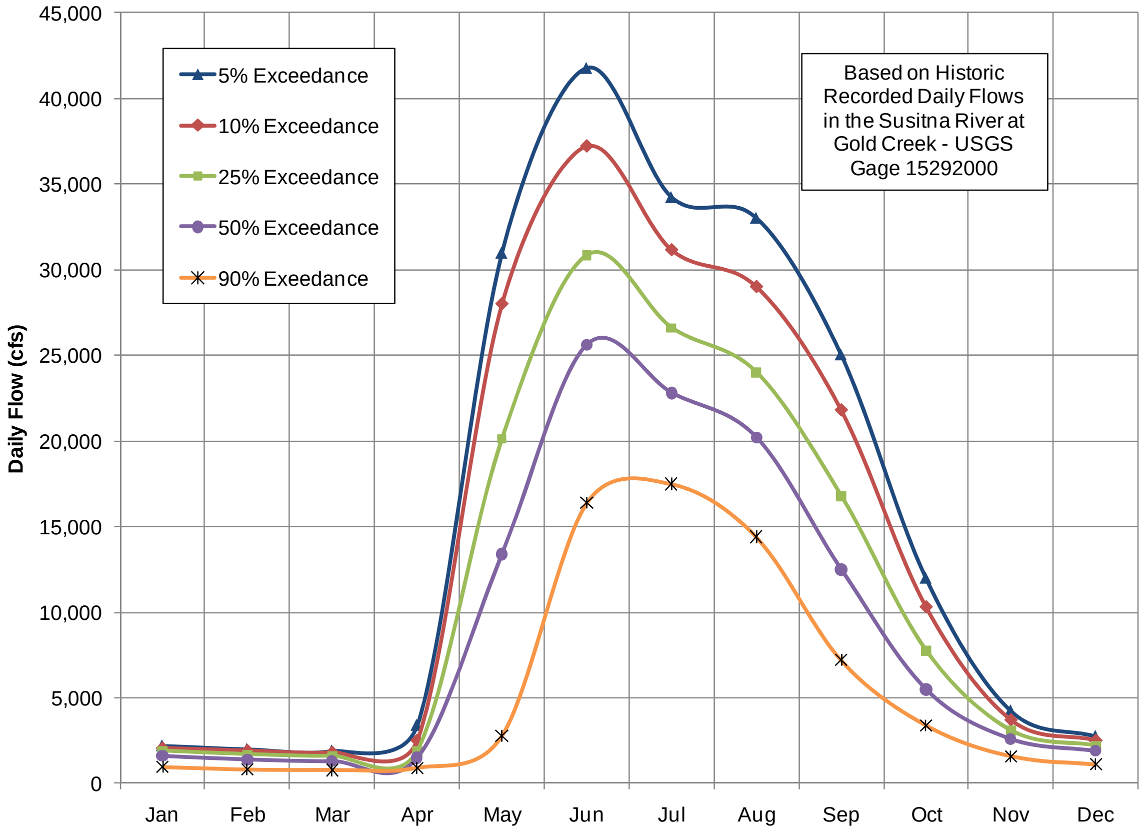

Figure 2: Flow Frequency – Susitna River at Gold Creek

HYDROLOGIC CHANGE

Global warming scenarios have projected greater temperature increases at higher latitudes. Over the past 50 years, Alaska has warmed at more than twice the rate of the rest of the United States' average. Its annual average temperature has increased 3.4°F, while winters have warmed even more, by 6.3°F (Karl, et al, 2009). As a result, climate change impacts could be expected to be much more pronounced in Alaska than in other regions of the United States. Among other effects, higher temperatures should contribute to earlier spring snowmelt, a higher percentage of precipitation falling as rain instead of snow, and glacier retreat.

The effect of increasing average annual temperatures on annual average streamflow is not easily predicted. Major factors other than temperature to be considered would include climate change effects on precipitation, evaporation, transpiration, snow ablation (direct change in phase from solid to vapor), and the rate of net loss to glaciers. Increased flows from glacial melt can be more than balanced by reduced runoff due to increased evaporation and transpiration. Projections of future average precipitation at a location are generally considered to be much less certain than projections of future average temperatures.

For the purpose of assessing the effects of climate change on long-term reservoir inflows to the Watana Hydroelectric Project, it is fortunate that a long-term USGS record of streamflow exists at Gold Creek. Average annual flows at Gold Creek for the complete calendar year period of record are plotted on Figure 3. A best fit linear trendline is also plotted as the straight red line through the recorded data. The trendline shows an essentially constant average annual flow rate over the period of record, with only a very slight, almost negligible, upward trend.

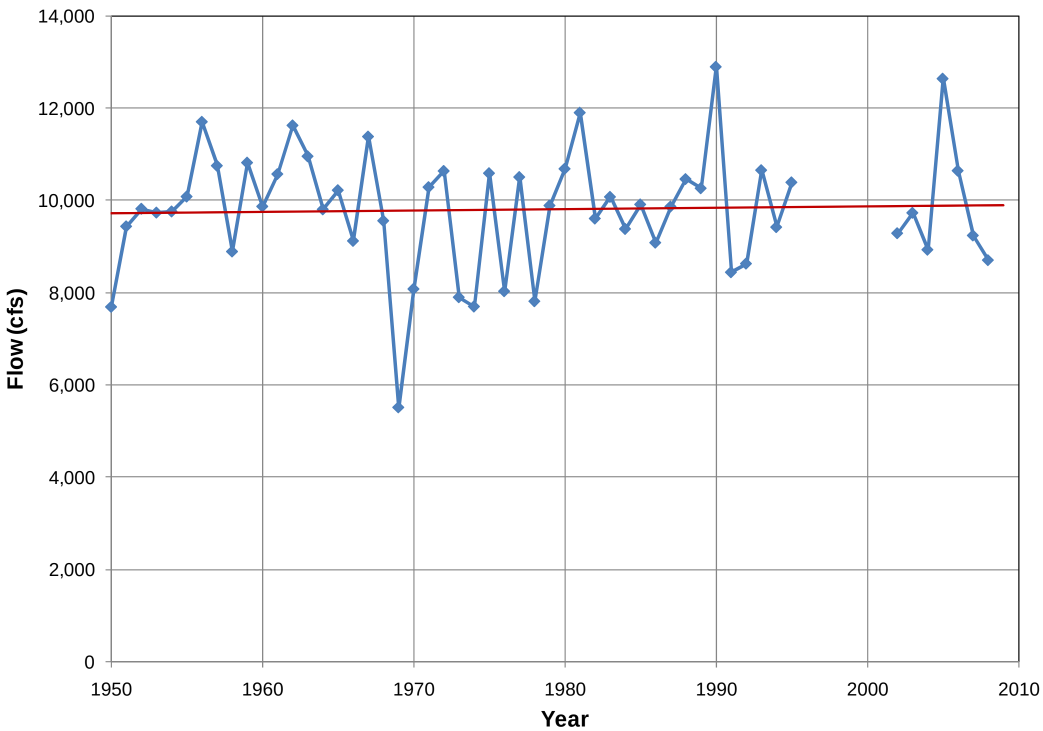

Figure 3: Average Annual Recorded Flows – Susitna River at Gold Creek

Analysis of monthly flow data at Gold Creek presents an entirely different picture from the annual data. As shown on Figure 4 for February data and Figure 5 for April data, the linear trendlines show a pronounced increase in average monthly flows over time. Statistical tests of significance indicate with very high reliability that the observed trends in streamflow are not random. The April trends are most significant and undoubtedly result from an earlier initiation of the spring snowmelt as well as more precipitation falling as rain instead of snow. If annual average flows remain constant while winter and early spring flows are increasing, flows in other months must be decreasing. A statistically significant decrease in flows has been observed in June, as shown on Figure 6. Although the percentage decrease in flows is less than the percentage increase in flow in other months, June is the month with the highest average flow (Figure 2) so that a smaller percentage change can have a greater effect.

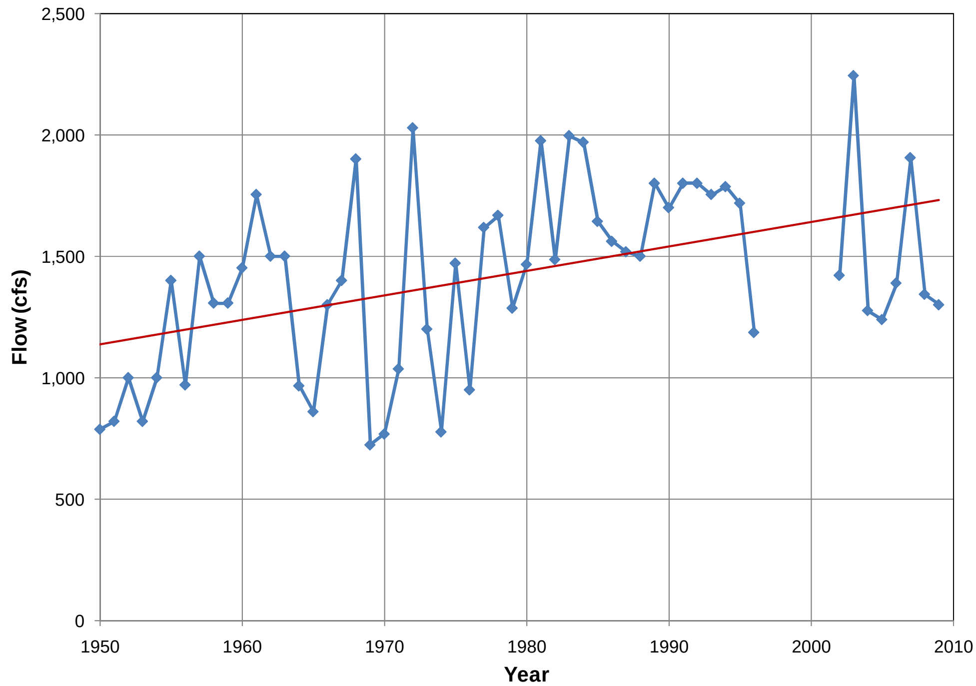

Figure 4: February Monthly Recorded Flows – Susitna River at Gold Creek

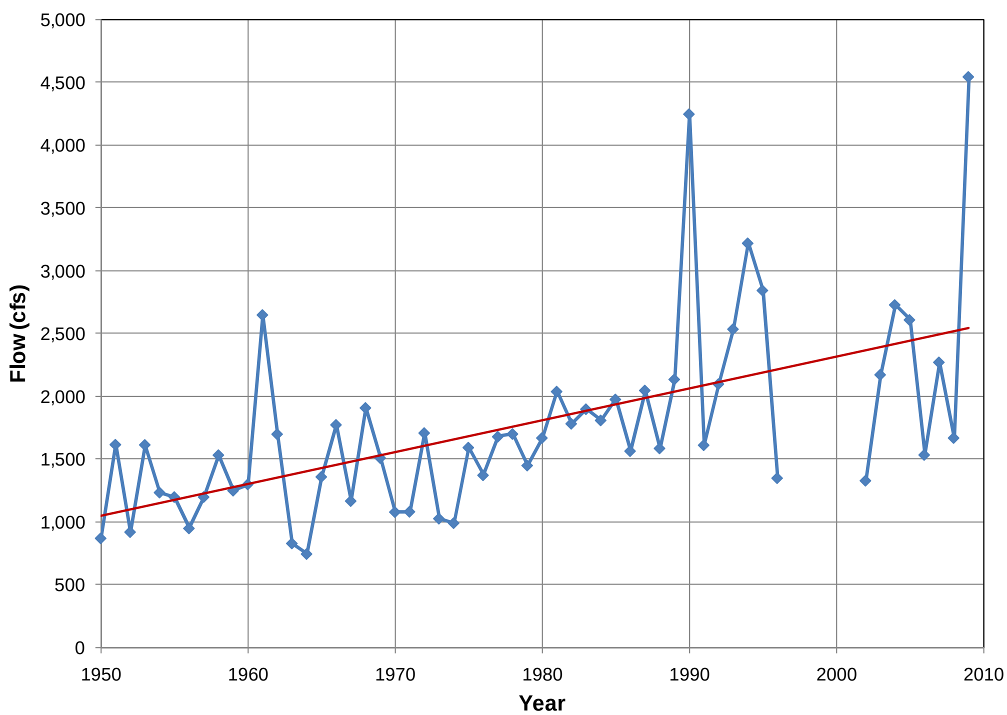

Figure 5: April Monthly Recorded Flows – Susitna River at Gold Creek

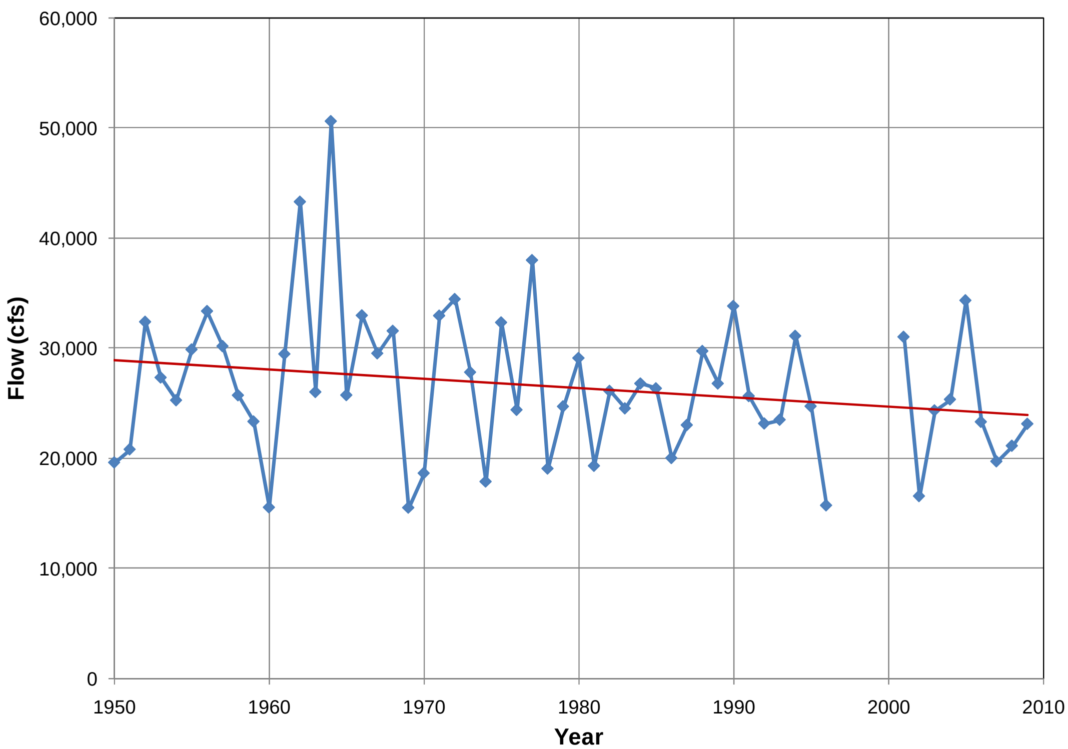

Figure 6: June Monthly Recorded Flows – Susitna River at Gold Creek

The observed seasonal flow trends on the Susitna River are significant because:

- Over the past 60 years, the unregulated flow trends have been similar to the seasonal flow changes that would result from reservoir operations, although they have been much smaller in magnitude.
- The observed flow trends may establish a different unregulated flow baseline for comparison with the projected future flow regime with the Watana Hydroelectric Project.
- The general trend to increased winter flows, the earlier initiation of spring snowmelt, and the reduction in peak snowmelt runoff are all favorable for increased firm and average total hydroelectric energy production.

Reservoir operation and power studies have traditionally used historic flow records as the basic hydrologic input data. Our plan is to use Watana reservoir inflows developed directly from USGS records as the basic hydrologic input data set for the reservoir operation and power studies. However, the foregoing information has indicated that there is reason to consider alternative hydrologic input data sets that account for potential future hydrologic change.

The most authoritative global projections of climate change result from an ensemble of 23 Atmosphere-Ocean General Circulation Models (AOGCMs) (IPCC 2007). One method to develop hydrologic data sets that account for climate change would be to begin with results from the 23 AOGCMs, downscale the temperature, precipitation and evaporation results for the Susitna watershed, and then develop a rainfall-runoff model to produce the Watana reservoir inflows. The AOGCMs yield the highest confidence for temperature results, with much lower confidence in precipitation results. After introducing substantial uncertainty in future evapotranspiration, this method would produce a wide variation in projected future runoff at Watana. Instead, we feel that the historic USGS flow data can be used to project potential future Watana inflows with much greater reliability. Developing potential future Watana hydrologic inflows could also involve stochastic hydrology methods beginning with alternative projections of monthly flow data statistics.

RESERVOIR OPERATION AND POWER STUDIES

Development of a reservoir operation and power study model is just being initiated at the present time. The initial input data set to the model will rely on basic input data used in previous studies for the Watana site including reservoir elevation-capacity data, the tailwater rating curve, and environmental release requirements. Generation results from the initial model run will be compared to previous results and any significant differences will be resolved to the extent possible. Input parameters will be revised as necessary, for example to determine the effects of increasing the plant capacity. The general operating objective will be to maximize firm energy during the low flow period from November 1 through April 30 and to maximize total energy during the remainder of the year.

REFERENCES

IPCC, 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, 996 pp.

Karl, Thomas R., Jerry M. Melillo, and Thomas C. Peterson, (eds.), 2009. *Global Climate Change Impacts in the United States*, Cambridge University Press.