IMPACT OF CLIMATE CHANGE ON WATER SUPPLY IN THE UPPER YUKON RIVER

by

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ABSTRACT

A study was carried out to determine the impact of the projected climate change on water supply in the Yukon River above Whitehorse. The system is glacier fed with peak flows in late summer. Earlier low elevation snowmelt keeps water levels high for most of the summer. Historical monthly values of temperature and precipitation were used to develop a relationship with streamflow. Changes in temperature and precipitation based on a projected 100 percent increase in CO_2 were used as a starting point to assess water supply impact. Evapotranspiration rates were estimated using a method which requires readily available parameters. These values were compared with projected monthly inflows to assess climate change impacts on the water balance.

INTRODUCTION

The upper Yukon River system provides flow for the operation of the hydroelectric plant at Whitehorse. For hydroelectric and flood mitigative purposes it is desirable to assess the impacts of the projected climate change on the streamflow of the upper Yukon River.

Multiple regression relationships were developed between monthly Marsh Lake inflows and climatological parameters for Whitehorse. Using this relationship with projected temperature and precipitation increases generated by the Canadian Climate Centre, General Circulation Model (GCM), monthly inflows to the system were developed for a post climate change scenario of a 100 percent increase in carbon dioxide in the atmosphere. Estimates of evapotranspiration were made to assess the impact of this process on the generated inflow hydrograph.

SETTING

The Yukon River originates in the glacier fields of the Coast Mountains of British Columbia and flows 2900 kilometres through Yukon Territory and the State of Alaska to the Bering Sea (figure 1). The 19,400 km^2 upper Yukon River above Whitehorse, lies within the Yukon Cordilleran physiographic region. Elevations range from 700 to 1500 metres in the east to 2400 metres in the rugged mountainous portion in the west. The upper Yukon River contains an extensive series of lakes which provide a significant amount of natural storage (figure 2). The system is controlled artificially during the winter months by the Marsh Lake control structure which transforms much of the lake system into a storage reservoir for the hydroelectric plant at Whitehorse.

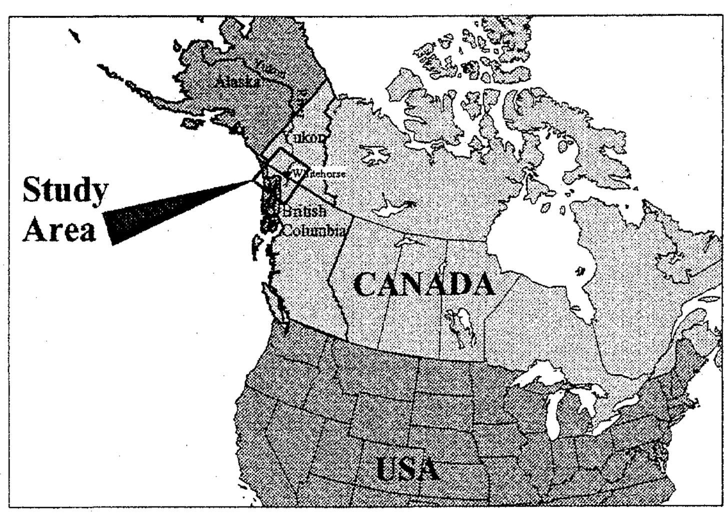

Figure 1 Location Map

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Paper presented Western Snow Conference 1994

Mean annual temperatures range from -1^{o}c on the leeward side of the mountains to -4^{o}c in the icefield areas. July is the warmest month with monthly mean temperatures of 10 to 15^{o}c. January is the coldest month with monthly mean temperatures of -10 to -25^{o}c. Precipitation in the basin is generally low with values of 200 to 300 mm though the western icefield area receives up to 1000 mm annually.

The mean annual flow of the upper Yukon River as represented by the Yukon River at Whitehorse is 242 m^3/s. A short distance downstream of Marsh Lake, flows at Whitehorse are essentially Marsh Lake outflows. Peak flows generally occur in the late summer in response to glacier and high elevation snowfield melt contributions (the Marsh Lake control structure is fully open between May 15 and September 15 hence the upper Yukon system is in an unregulated mode during this period). The mean maximum monthly discharge and mean annual maximum instantaneous discharge are 493 and 521 m^3/s respectively (figure 3). Minimum flows are regulated for hydroelectric operation purposes. The mean minimum monthly discharge of 102 m^3/s occurs in April. This value is approximately twice the unregulated value.

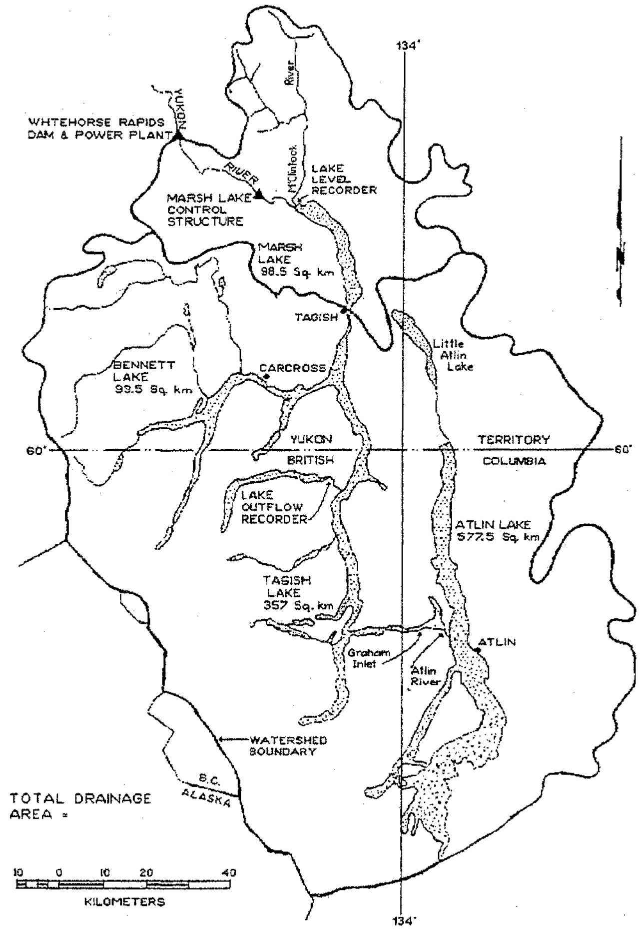

Figure 2 Upper Yukon River System

For study purposes the inflows to Marsh Lake were calculated using the equation of continuity with measured downstream discharge and lake stage. This procedure removes the winter storage influence provided by the Marsh Lake control structure and provides an accurate estimate of available water for power generation.

CLIMATOLOGICAL DATABASE

Climatic data is available for several communities, however, due to the significant amount of missing data and lack of solar radiation data or an index thereof, only Whitehorse records were found suitable for use.

Simulated monthly temperature and precipitation data based on the projected climate change scenario of a 100 percent increase of CO_2 in the atmosphere were provided by the Canadian Climate Centre and are based on a global circulation model (GCM) developed by the Centre in 1988. This information was used as a starting point and was not evaluated or discussed in detail.

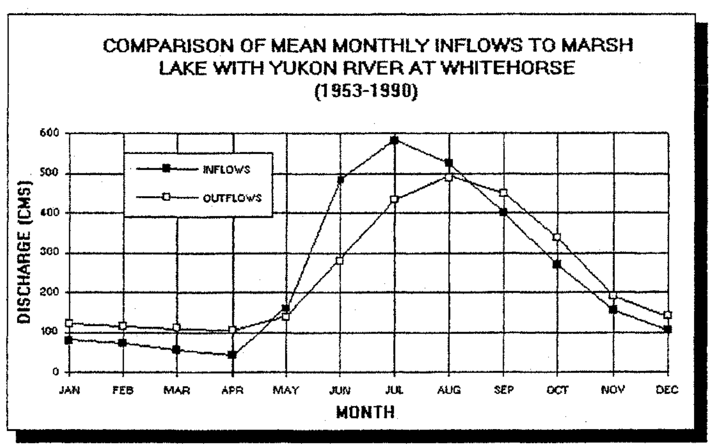

Figure 3 Marsh Lake Inflows and Yukon River at Whitehorse

Multiple regression relationships were developed between temperature and precipitation parameters for Whitehorse, and calculated inflows to Marsh Lake. These relationships were then used to derive a post climate change hydrograph for the system.

Developed relationships for late spring and summer flows are relatively good while winter flows were more difficult to predict. The poorest relationship is for April which is the month of the lowest annual flows.

The most significant independent parameter for late spring and summer high flows was found to be monthly mean temperature for the month of the flow being estimated. Other parameters which were utilized included cumulative winter and summer temperature and precipitation, and various combinations of monthly values. There were no dominant independent variables for winter low flow periods.

Projected values of temperature and precipitation based a 100 percent increase in atmospheric carbon dioxide were used to develop the post climate change hydrograph (figure 4).

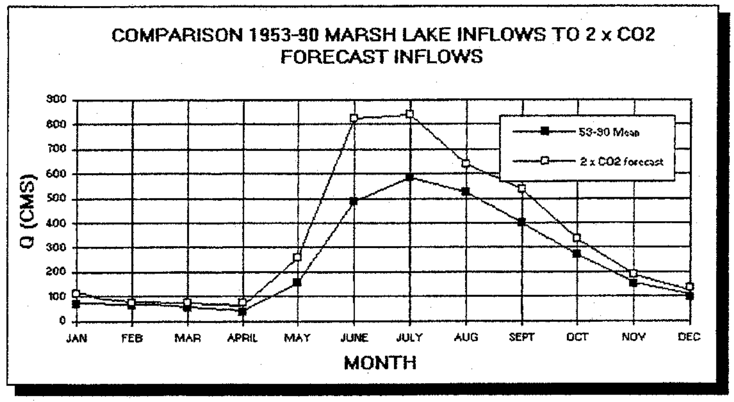

Figure 4 Marsh Lake Inflows

EVAPOTRANSPIRATION

Changes in evapotranspiration are partially accounted in the development of the relationship between Marsh Lake inflows and climatological parameters. This would not be the case during the months when significant temperature changes and subsequent alterations to the energy balance are projected. To develop a feeling for changes to the energy balance, evapotranspiration for the basin was estimated using a computer model developed by Morton et al. (1985) based on a methodology developed by Morton. The computer program was operated using a user friendly shell developed by the Department of Environment's National Hydrology Research Institute (NHRI). The computer model estimates actual evaporation and transpiration using readily available temperature, humidity and sunshine duration data. For the purpose of estimating post climate change evapotranspiration, functional linear relationships were developed between monthly air temperatures at Whitehorse and dewpoint temperature, and, monthly precipitation and sunshine hours.

Useable relationships were developed for estimating dewpoint temperature and sunshine hours. Good results were obtained between air temperature and dewpoint temperature especially for the winter months (figure 5). The relationship between precipitation and sunshine hours is not as good, but obvious trends are apparent (figure 6). Best results were obtained for the summer high precipitation months.

Preliminarily evapotranspiration estimates were made for the Upper Yukon system using Whitehorse climatological information. Provided monthly temperature and precipitation values indicate a three fold increase in mean annual temperature and a 14 percent increase in mean annual precipitation. Dewpoint temperature is expected to increase by close to a factor of two, and sunshine hours are expected to decrease slightly. Estimated post climate change evapotranspiration indicates a 30 percent decrease in annual actual evapotranspiration will occur. The greatest change is expected to occur during the summer months when actual evapotranspiration rates are projected to be about half of current rates.

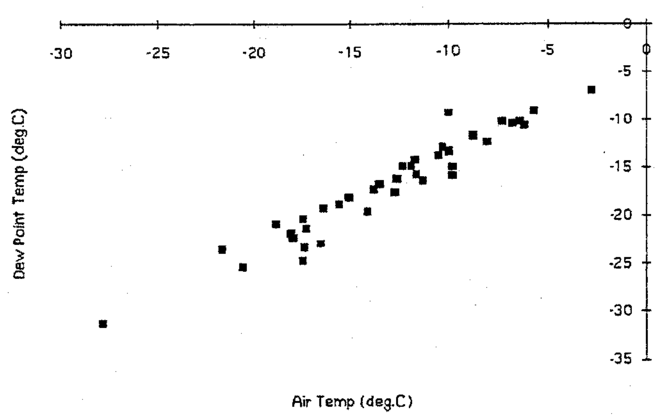

Figure 5 February Whitehorse Air Temperature / Dew Point

The projected change in actual evapotranspiration is significant and should be viewed with caution. Of potential sources of error, perhaps the greatest is associated with the soil heat flux and its impact on net radiation, which is not considered by the model (Granger, 1994). Estimates of net radiation may be off by 5 to 8 percent during the summer when the soil is thawed, and as much as 20 percent during the early spring. Other potential sources of error are associated with changes to physical characteristics of the basin including the vegetation cover, permafrost, and area of glaciers within the basin. Changes in lake and wetland storage may also be a factor in altering the energy and water balance of the system.

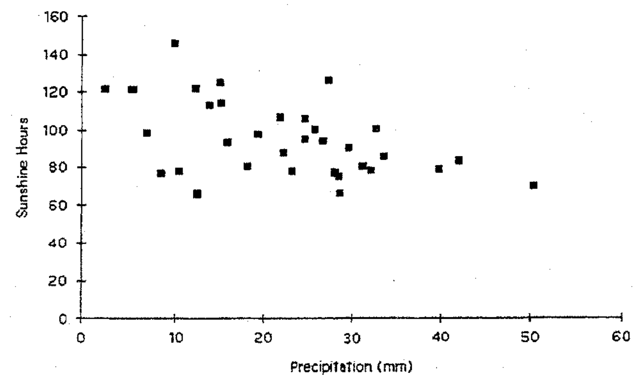

Figure 6 October Whitehorse Precipitation / Sunshine Hours

DISCUSSION

Multiple regression relationships were developed between monthly Marsh Lake inflows and climatological parameters for Whitehorse. Reasonable relationships were obtained for most months though results were better for the open water season. Using this relationship with projected temperature and precipitation increases generated by the Canadian Climate Centre GCM, monthly inflows to the system were developed for a post climate change scenario of a 100 percent increase in carbon dioxide in the atmosphere. This procedure resulted in a 39 Percent increase in annual inflows to the upper Yukon River system.

A classical water balance was not carried out; however, estimates of evapotranspiration were made to assess the impact of this process on the generated inflow hydrograph. This study component indicated that annual rates of actual evapotranspiration would decrease by 30 percent. Rates of this magnitude would have a significant impact on the developed inflow hydrograph by further increasing water yield. This change may be high due to unaccounted sources of error associated with energy balance assumptions and changes to physical parameters of the basin. Due to the uncertainty associated with evapotranspiration estimates, the developed hydrograph was not adjusted, and this information is provided for discussion purposes.

ACKNOWLEDGEMENTS

The authors wish to thank Raoul Granger, NHRI for his assistance with the evapotranspiration component. Assistance in running the evapotranspiration model was provided by Leslie Gomm. Martin Jasek and Bill Slater produced the graphics. Diane Nikitiuk supplied the title and Barbara Deklerk for the word processing.

REFERENCES

Granger, R. 1994. Personal Communication. Environment Canada, National Hydrology Research Centre, Saskatoon, Saskatchewan.

Morton, F.I., F. Ricard and S. Fogarasi. 1985. Operational Estimates of Areal Evapotranspiration and Lake Evaporation-Program WREVAP. Environment Canada, National Hydrology Research Institute, NHRI Paper No. 24, Ottawa, Ontario.

NHRI. Undated. Unpublished Internal Documentation Report. Saskatoon, Saskatchewan.

Oswald, E.T. and J.P. Senyk. 1977. Ecoregions of Yukon Territory. Fisheries and Environment Canada, Canadian Forestry Service, Pacific Forest Research Station, Victoria, British Columbia.

Wahl, H.E., D.B. Fraser, R.C. Harvey, and J.B. Maxwell. 1987. Climate of Yukon. Environment Canada, Atmospheric Environment Service, Climatological Studies Number 40, Ottawa, Ontario.