WaterSMART Solutions Ltd.

Assessing Climate Change Impacts on Operational Flows in the Bow River Basin- Continued work as part of the Bow River Project

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1.0 Introduction

1.1 Background

Changes in climate can impact hydrological regimes and the operating systems that attempt to control the river for various water uses. This document describes the work that is part of an initial look at potential climate change impacts in the Bow River Basin, and how changes in climate could impact Bow River operations. This information will be used to give consortium members an idea of the range of potential impacts on the system as the Bow River Project (BRP) work continues (BRPRC, 2010). The hope is in another phase of the BRP that more work on the impacts of climate variability and change in the basin can be looked at to assess potential challenges that changes in climate may have on river system operations. The idea is in the future to do a similar modelling project in other Alberta water basins as was done in the Bow, with more rigours climate change work for each basin.

1.2 Bow River Operational Model (BROM)

In 2010, the Bow River Project Research Consortium was established to explore options for re-managing the river system from the headwaters to its confluence with the Oldman River. The Consortium is a collaborative group of water users and managers whose members control approximately 95% of water allocations and estimated water use in the Bow River Basin (BRPRC, 2010). Participants worked with an interactive, hydrologic simulation model to develop plausible and achievable scenarios for protecting the health of the river throughout the basin and meeting the needs of water users. The fully functioning, data-loaded Bow River Operational Model (BROM) was a very significant output of the BRP. BROM will be publicly available for further analysis of the Bow River System and can be adapted for other river systems in Alberta. The model quantifies and maps water supply and usage, establishes flow thresholds and maintains a full suite of performance measures. This tool enables users to establish and test plausible scenarios that balance future water needs, environmental objectives, social considerations, and economic feasibility.

For this piece of climate change work, there were three methods applied from current information and ideas to provide a range of potential impacts that a change in climate could have on flows and operations. These impacts on the system would be assessed using the BROM, which was developed during Phase III of the BRP. These methods were suggested as good starting points by researchers at the Universities of Lethbridge and Regina. A brief description of each method and how it was modelled are below. All of the work here was done using the current base case on version 3.0 of BROM.

2.0 Climate Change Methods Applied to BROM

The three methods applied for this work were chosen to assess a range of potential impacts that a change in climate could have on flows and operations in the Bow River Basin. These methods provide estimates from a range of climate forecasts based on wet, median, and dry conditions. Physical model output from the NCAR A1B model provides estimates under 'wet' conditions, physical model output from the CGCM3 B1 model provides estimates under 'median' conditions, and the Empirical Trend Projection (ETP) method provides estimates under 'dry' conditions. The lowest flows method described in Section 2.3 helps to assess how a prolonged period of low flows could impact the river system under current conditions or under a potential perturbed future climate.

2.1 Applying Bow River Empirical Trend Projections (ETP)

Empirical Trend Projection (ETP) for the Bow River, from a study of changing summer flows in the Rocky Mountains (Rood et al., 2008) was applied to all the inflows in BROM. The ETP values are applied as percent monthly changes to flows (e.g. a factor of .89 was 11% decrease). An OCL (operations control language) pattern called "BowClimateFactor" was created (Figure 1), and the pattern was multiplied by each of the inflows in 'set_inflows.ocl'.

BowClimateFactor	1			1.0	1	1	1.1
BowClimateFactor					1	15	1.1
BowClimateFactor					2	15	1.1
BowClimateFactor					3	15	1.12
BowClimateFactor					4	15	0.92
BowClimateFactor					5	15	0.8
BowClimateFactor					6	15	0.79
BowClimateFactor					7	15	0.78
BowClimateFactor					8	15	0.75
BowClimateFactor					9	15	0.82
BowClimateFactor					10	15	0.95
BowClimateFactor					11	15	1.05
BowClimateFactor					12	15	1.1
BowClimateFactor					12	31	1.1

Figure 1: Screen shot of ETP input into BROM

2.2 Applying physical model output from North Saskatchewan River climate change work to the Bow River

The upper North Saskatchewan River Basin (UNSRB) was modelled in 2010 using a physically-based model to assess impacts of climate change on streamflow in the Cline River Watershed (Kienzle et al., 2011). The Cline River Watershed is in the SW corner of the UNSRB, which borders the upper NE portion of the Bow River Watershed, where most of the inflows into BROM exist (headwaters for The Bow). Outputs from the 2050s for two of the climate change scenarios applied in that work (CGCM3 B1 and NCAR A1B) were used to create a climate factor for input into BROM. CGCM3 was the median scenario, and NCAR A1B was the hottest/wetter scenario from the UNSRB work. It should be noted that these scenarios all projected annual increases in precipitation relative to the historic normals. Also, these results were from runs where glacier melt was not being modelled since the new glacier melt routine in the model was not refined enough at that time to simulate future melt water outflows from glaciers. The input was applied as a percent change to streamflow from the climate scenarios output relative to the simulated baseline of 1961-1990. OCL patterns called "BowClimateFactor_NCAR" and "BowClimateFactor_CGCM" were created (Figure 2), and the pattern was multiplied by each of the inflows in 'set_inflows.ocl'. These patterns were applied to all the inflows in BROM on a bi-monthly or monthly time scale based on magnitude of weekly changes from the model output.

BowClimateFactor_NCAR	1			1.0	1	1	1.27
BowClimateFactor_NCAR					2	26	1.3
BowClimateFactor_NCAR					4	29	1.29
BowClimateFactor_NCAR					5	13	1.14
BowClimateFactor_NCAR					5	27	0.91
BowClimateFactor_NCAR					6	10	1.0
BowClimateFactor_NCAR					6	24	1.03
BowClimateFactor_NCAR					7	8	1.02
BowClimateFactor_NCAR					8	5	0.98
BowClimateFactor_NCAR					8	19	0.92
BowClimateFactor_NCAR					9	2	0.87
BowClimateFactor_NCAR					9	16	0.9
BowClimateFactor_NCAR					9	30	1.06
BowClimateFactor_NCAR					10	14	1.27
BowClimateFactor_NCAR					12	31	1.27

Figure 2: Screen shot of the modelled output from the NCAR A1B scenario being input into BROM

2.3 Applying sequential lowest flow years

Historic and tree ring data have shown that there have been floods and droughts longer in duration and magnitude then anything in the recorded streamflow records (Sauchyn et al., 2003), which indicates that future flood/drought events could be far more severe than modern water management has previously experienced. In order to show how a longer term drought might impact the system, the inflow records in BROM were cut and pasted to have the eight lowest streamflow years together in the same decade. Using existing data in the model was convenient and helped to keep much of the variability in the record in terms of streamflow. This method of the lowest flow years was to help give the stakeholders an idea of what a long term 'drought' could look like, realizing it could be worse (such as magnitude and duration of parts of the 1700's).

Table 1: Flow years that were replaced by low flow years to create a prolonged low flow period in BROM

Original Year	Year Change
1930	1988
1931	1931
1932	1984
1933	1949
1934	1944(-Feb29)
1935	1931
1936	1936
1937	1936 (-Feb29)
1938	1941
1939	1977

All the inflows in BROM were summed on an annual basis to determine the lowest flow years. Based on the summed inflows, the lowest streamflow years are (not in order of severity), 31, 36, 41, 44, 49, 77, 84, 88. The flow data for the eight lowest flow years were then input for the years 1930-37. Original data was kept in for 1931 and 1936 as they were both one of the 8 lowest flow years, so the modified record goes from 1930-1939. Since 1936 and 1944 were leap years, when they were filled in for nonleap years February 29th was removed (Table 1). The 1930s were used as the decade for this exercise as the climate data in the model for the 1930s would be most representative of a drought period. The only direct climate data in the model is precipitation/evaporation time series for reservoirs, and those time series were not manipulated for these modelling runs. This method of having sequential low flow years will be referred to as the 'lowest flows'.

2.4 Combination of methods

Once the data for the lowest flows were completed they were added into the model runs that also had ETP and model outputs from the physical model. This was done to combine the methods that were suggested for this initial set of work, as a combination of prolonged low flow periods, as well as shifts in hydrological patterns are likely impacts a changing climate. Based on the literature, earlier snow melts and lower summer flows/higher winter flows are expected (Stewart et al., 2005; Rood et al., 2008) as seen in ETP and model output methods, as well as longer/more severe droughts (Sauchyn et al., 2003) as seen in the lowest flows method. This was done to broaden the range of potential impacts that could be seen in the future and how they impact the current and preferred operating rules for the Bow River system.

3.0 Results

As part of Phase III of the BRP, a series of performance measures (PMs) were created to help evaluate the outcomes for each of the model runs. The PMs are generated automatically using the using the Plot Maker tool. Days with some shortage (Figures 3-4) and Bassano Flow Classification (Figures 5-6) were the two of the PMs that were assessed during the BRP work that are presented here to show some of the impacts the climate scenarios had on operations. All of the figures show the whole modelling record (1928-1995) unless otherwise indicated.

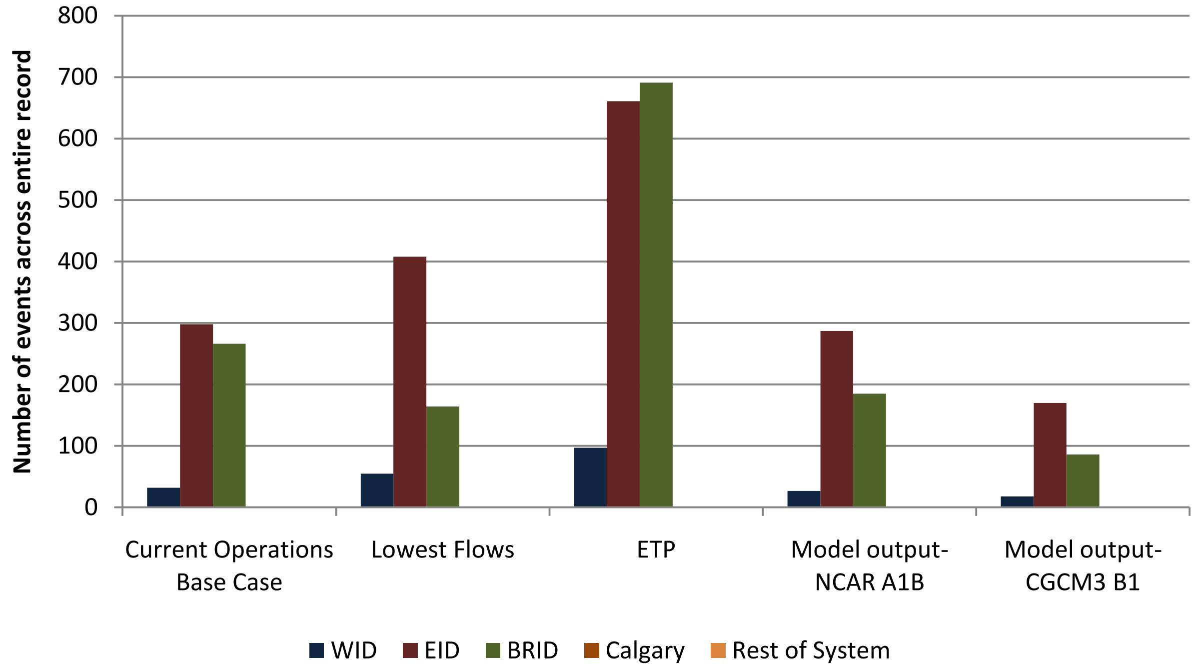

Figure 3: Total number of days with shortages for each major user of the system from all three methods

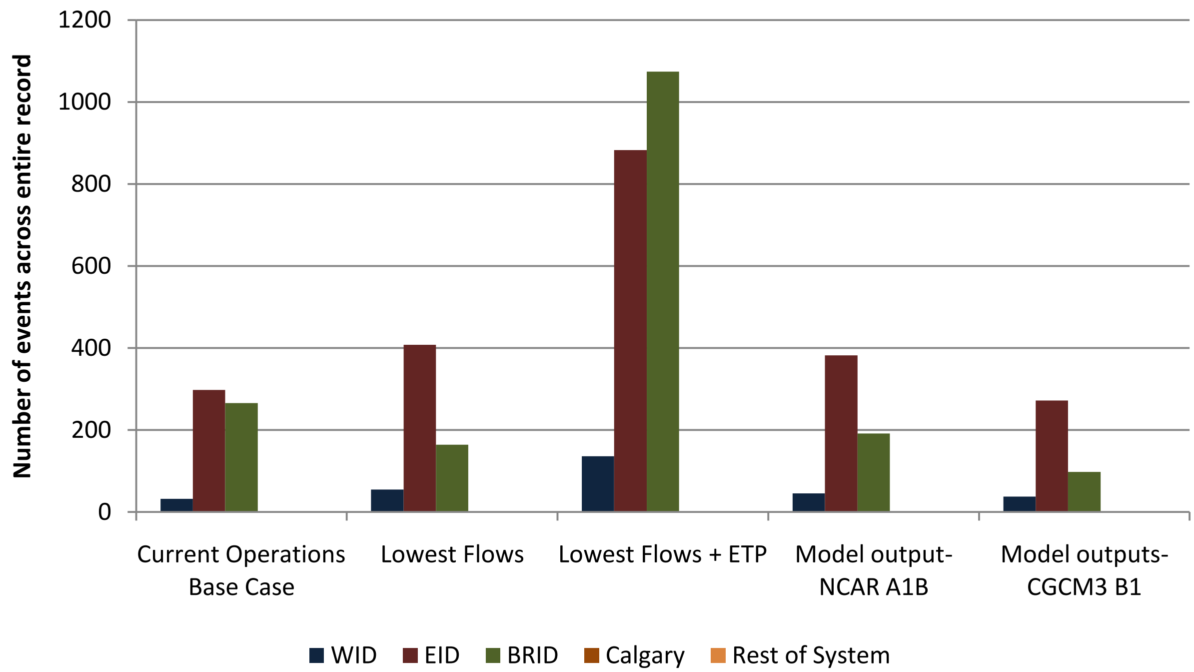

Figure 4: Total number of days with shortages for each major user of the system with all scenarios having the lowest flow period.

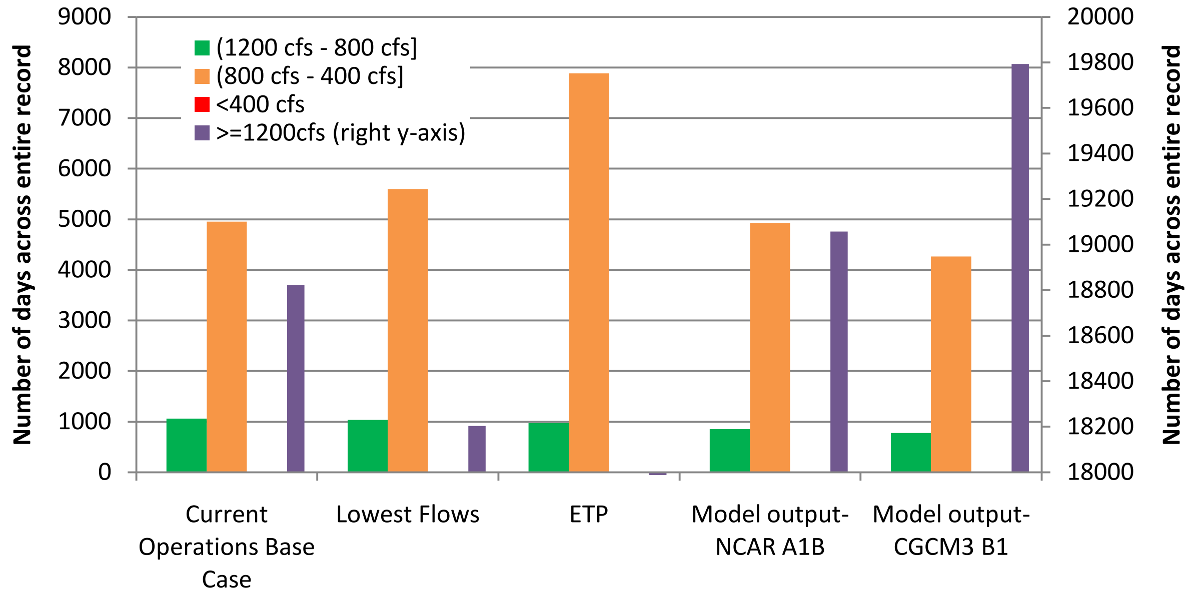

Figure 5: Flow classification at Bassano for all the three methods.

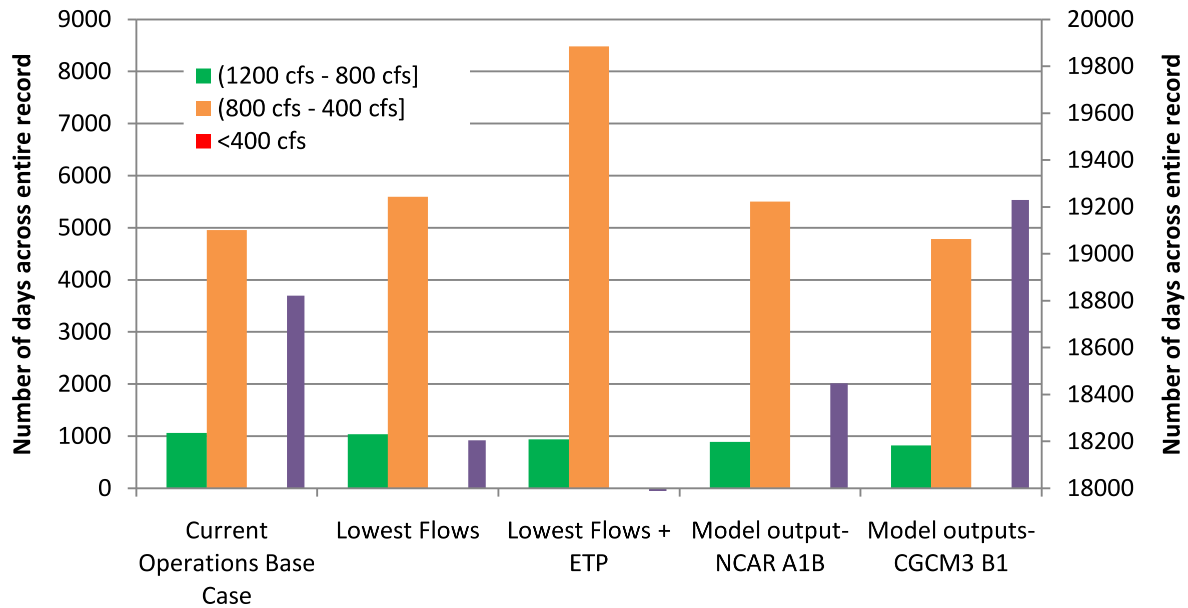

Figure 6: Flow classification at Bassano with all scenarios having the lowest flow period.

Daily results for all of the methods were also looked at for average daily flows below Bassano, and how those differed from the current base case. Low flows downstream of Bassano were of particular concern during the BRP, and are often used as a benchmark or indicator to conditions in upstream segments of the river. Daily results are the average daily flow for each Julian Day for the whole modelling record (Figures 7-9). <u>Please ignore the sharp drop in flows starting the first week of the year.</u> This is a result of the interpolated portion of the normal curves for the TransAlta reservoirs which is information we are hoping to have updated this year.

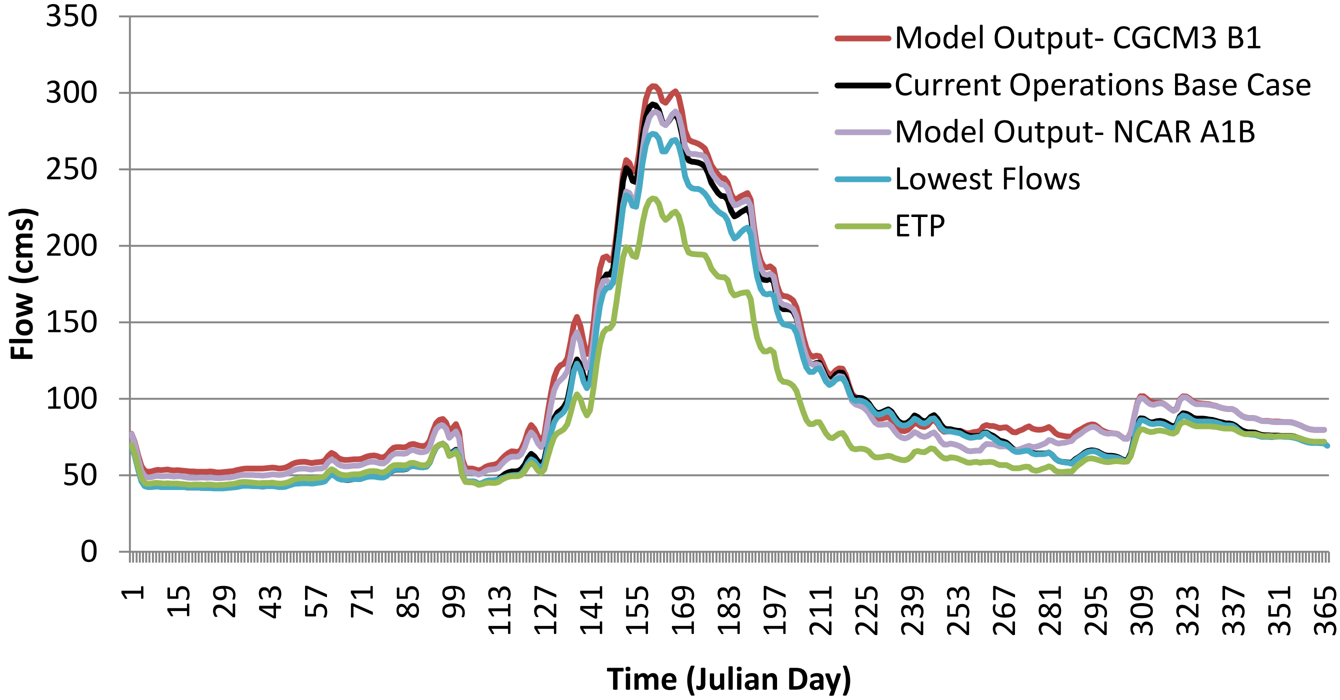

Figure 7: Average daily flows for all three methods relative to current base.

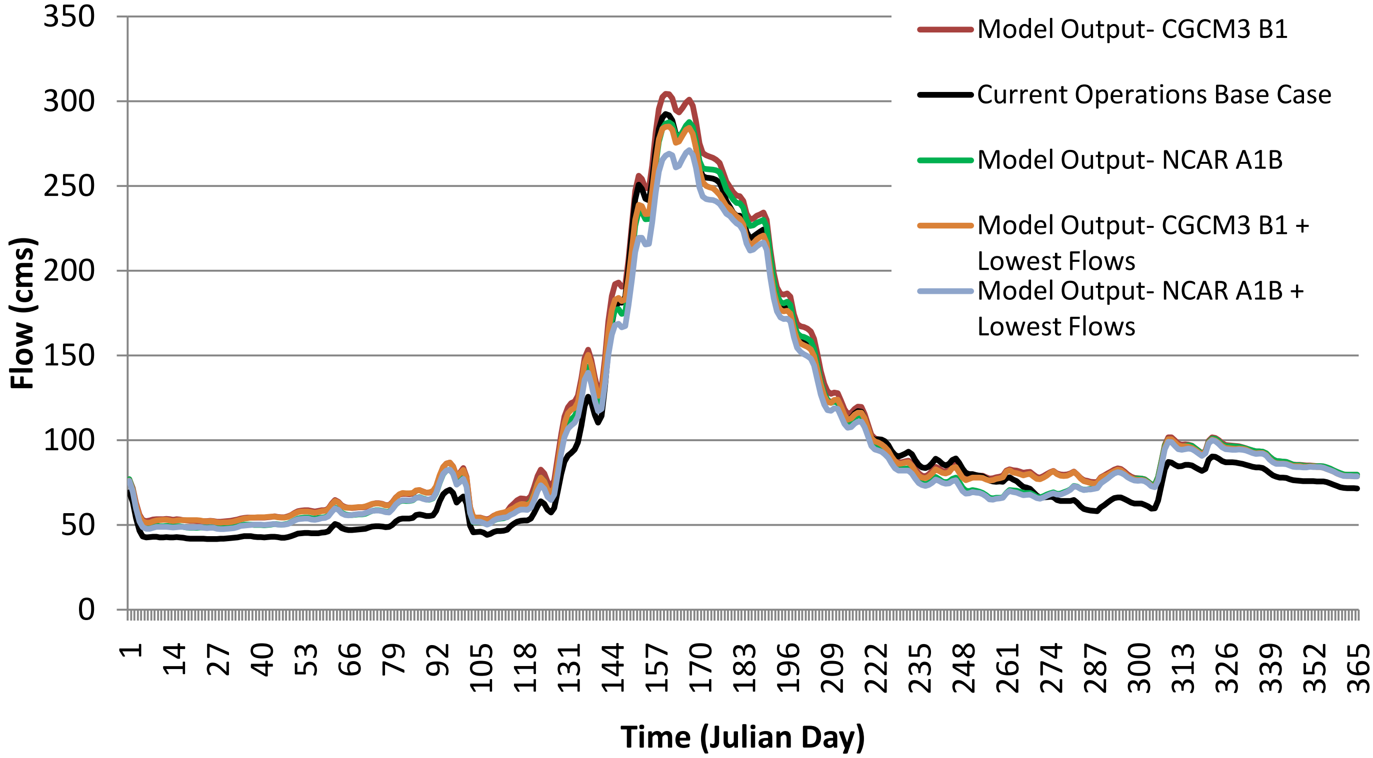

Figure 8: Average daily flows for model outputs with the lowest flows relative to current base.

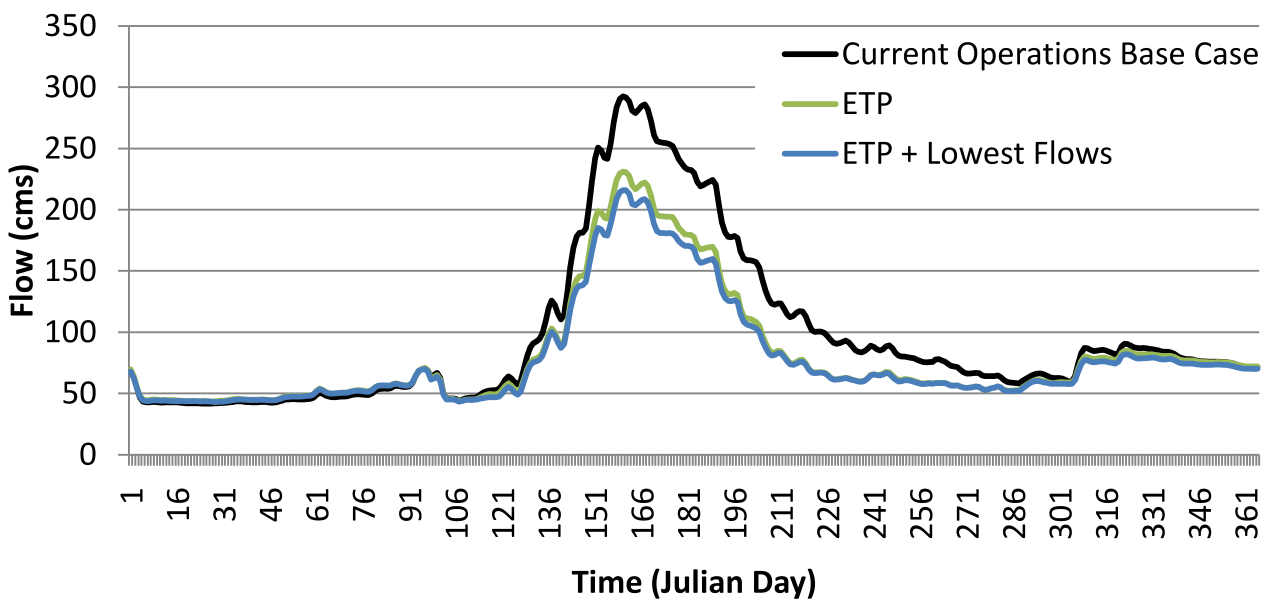

Figure 9: Average daily flows for ETP with the lowest flows relative to current base.

As the ETP method had the biggest impact on flows of the three methods, the ETP method was applied to the 'preferred scenario', which includes the preferred set of operating rules that were established by the consortium as part of Phase III of the BRP (see BRPRC, 2010 for details). This preferred set of rules will be tested in a live simulation with stakeholders in October 2011, where the consortium will attempt to establish a refined set of operating rules that can be used in a real life test year on the Bow River (in either 2012 or 2013). The idea here was to see how the preferred scenario would fair with the changes in streamflow versus the current operating rules (Figure 10).

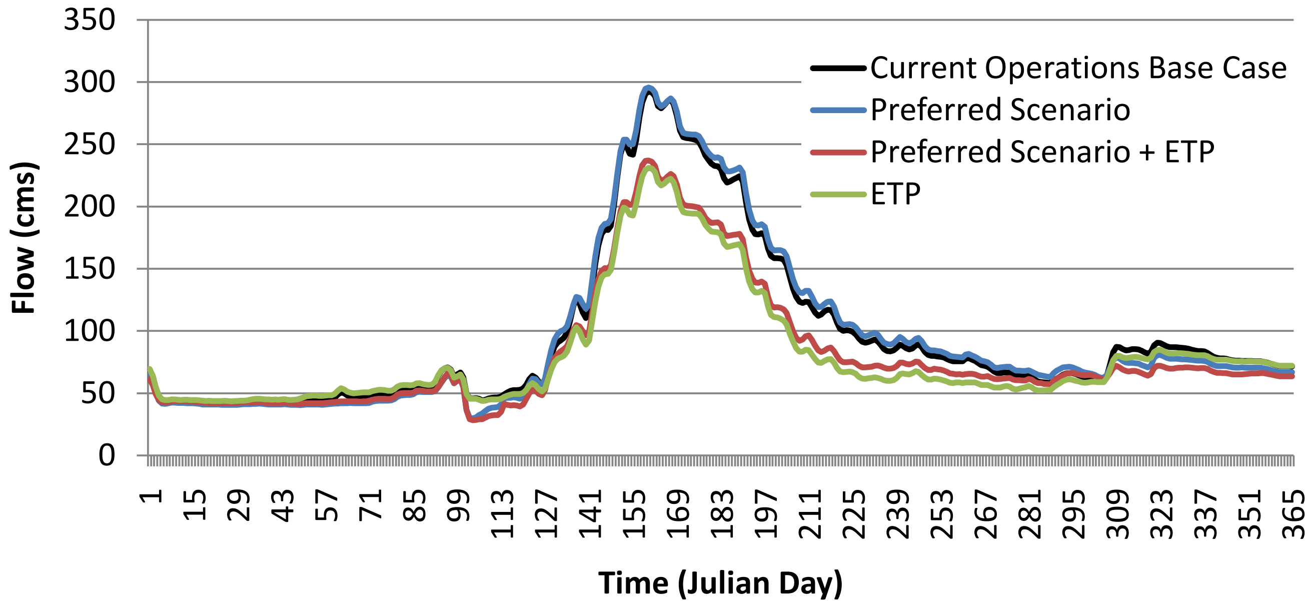

Figure 10: Average daily flows for ETP relative to current base operations and the preferred operating rules developed during phase 3 of the BRP.

4.0 Discussion

ETPs had the largest impacts on flows. The model outputs from the CGCM3 and NCAR both projected annual increases in precipitation, so at times flows were higher than under current conditions, although late summer/early fall flows were lower than current conditions. ETP and lowest flow methods had negative impacts on shortages, while the model output from CGCM3 and NCAR actually reduced shortages (Figures 3-4); likely due to the increased precipitation associated with those model runs. All of the climate change methods applied to BROM had negative impacts on flows below Bassano (Figures 5-6) except for the application of the CGCM3 output which had comparable results to the current base run.

Flows were always impacted more when the lowest flow method was added onto any of the other methods (Figures 4, 6, 8, 9). This would be expected when an increase in the number of low flow years is applied to reduced flows over parts of the year.

Figure 10 shows the differences in how the current operating rules governing the operations in the Bow River and the preferred rules developed in Phase III of the BRP handle a change to the system. The preferred scenario resulted in better flows during the key months of the year when compared to current operating rules. The preferred set of rules will not prevent shortages or low flows from occurring, but can help to better manage low flows and regional demands during low flow periods. These preferred rules have yet to be fully explored, and planned simulation exercises in the fall of 2011 could yield rules that provide better flows under negatively impacted river flows.

5.0 Conclusions

This work was done to provide some realistic insight into climate change impacts in the Bow Basin and how potential changes could impact operations on the Bow River System. This work was based on work already completed in other studies, and concepts that would best illustrate potential impacts on the basin. Moving forward, this work should be used to illustrate to consortium members and new participants/stakeholders in the continuing Bow River work on what climate change impacts could look like and how the current and proposed operating rules and logic deal with those changes. This work is meant to be an initial step in helping to build operating rules around potential changes to streamflow and how to adapt to those from an operations stand point. As work in the Bow Basin continues, new and more rigorous climate change impacts could be applied to the runs in BROM to further refine proposed operating rules.

6.0 References

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