Memo

To: Wei Zeng

From: Hailian Liang

Cc: Feng Jiang

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Subject: Analysis of Flow Gaps at Bainbridge

This memo describes how flow gaps at Bainbridge, as depicted by our ACF Water Availability Resource Assessment model, came into existence based on the unimpaired flow (UIF) data and the demand at five nodes in the Flint River Basin. The nodes used are Montezuma, Albany, Newton, Milford, and Bainbridge. The flow direction is illustrated in Figure 1. The results are summarized in Table 1 and Table 2. Flow gap for the entire period of record and August 1986 are shown in Figure 2 and 3, respectively. The frequency of flow gap is shown in Figure 4.

Flow gap at Bainbridge is a combined result of lower basin water use and the upper basin diversion at Montezuma. The upper basin diversion, as modeled, takes place whenever the combined storage in the upper basin is less than full and whenever the storage is insufficient to meet upper basin demand. The model setting allows for such diversions to take place whenever the upper basin Flow Regime (at Montezuma Planning Node) is met. However, because of natural hydrological heterogeneity, meeting upper basin Flow Regime does not guarantee subsequent meeting of lower basin Flow Regime. For example, the upper basin may be slightly wetter than monthly 7Q10 conditions, providing the opportunity for storage of flow above monthly 7Q10 level. At the same time, the lower basin (and the entire basin as a whole) may be experiencing drought conditions under which the whole basin Unimpaired Flow (at the Bainbridge Planning Node) is lower than its corresponding monthly 7Q10. When this happens, any diversion/demand from the upper basin and demand from the lower basin may cause modeled flow at Bainbridge to be lower than Unimpaired Flow (i.e. Flow Regime at this moment), and consequently causing a gap to Flow Regime.

In order to identify appropriate management strategies to address these gaps, it is very important to isolate the causes of the gaps. We used post-processing of the modeling results to do just that.

The comparison of flow gap summaries including/excluding the diversion for the entire period of record is shown in Table 1. It can be seen that the diversion at Montezuma increased the both average and maximum values of shortfall at Bainbridge. However, the diversion did not change the chance of shortfall occurring.

Table 1. Summary of flow gap at Bainbridge.

Scenario	Length of Shortfall (% of time)	Average Shortfall (cfs)	Long-term Average Flow (cfs)	Maximum Shortfall (cfs)	Correspondi ng Flow Regime (cfs)
Total Flow Gap	13%	361 (233 MGD)	7880 (5093 MGD)	1377 (890 MGD)	2506 (1620 MGD)
Due to Lower Basin Water Use	13%	339 (219 MGD)	7880 (5093 MGD)	816 (528 MGD)	2506 (1620 MGD)
Due to Upper Basin Diversion	6%	72 (46 MGD)	7880 (5093 MGD)	636 (411 MGD)	4246 (2744 MGD)

Considering the diversion at Montezuma, there are four days showing flow gaps above 1000 cfs at Bainbridge (as shown in Table 2). The maximum flow gap occurred on August 14, 1986, with a value of 1377 cfs to which the diversion at Montezuma contributed 561 cfs (41% of the total flow gap). The second large flow gap occurred on August 13, 1986, with a value of 1218 cfs to which the diversion at Montezuma contributed 402 cfs (33% of the total flow gap). The third large flow gap occurred on August 15, 1986, with a value of 1181 cfs to which the diversion at Montezuma contributed 365 cfs (31% of the total flow gap). The forth large flow gap occurred on August 26, 1985, with a value of 1058 cfs to which the diversion at Montezuma contributed 242 cfs (23% of the total flow gap).

Approach Used to Determine the Flow Gap

- **Total Flow Gap**
  Flow Gap = Flow Regime Target – Simulated Flow
  Simulated flow=Outflow at Montezuma + Sum of UIF at other 4 nodes – Sum of Demand at other 4 nodes

  Here, the demand at Montezuma is included in diversion at Montezuma.

- **Flow Gap Due to Upper Basin Diversion**
  Flow Gap = Flow Regime Target – Simulated Flow
  Simulated flow=Outflow at Montezuma + Sum of UIF at other 4 nodes

- **Flow Gap Due to Lower Basin Water Use**
  Flow Gap = Flow Gap Including the Diversion – Flow Gap Due to Diversion

Table 2. Summary of large flow gap.

	I	II	III	IV
	8/26/1985	8/13/1986	8/14/1986	8/15/0986
Flow regime target (cfs)	2424	2368	2506	2325
Simulated flow including diversion (cfs)	1366	1150	1129	1144
Total Flow gap (cfs)	1058	1218	**1377**	1181
Flow gap due to diversion (cfs)	242 (23%)	402 (33%)	561 (41%)	365 (31%)
Flow gap due to water use (cfs)	816 (77%)	816 (67%)	816 (59%)	816 (69%)

The UIF and the demand data at each node were used to derive the flow gap at Bainbridge are shown in Table 3.

Table 3. UIF and demand data and the simulated flow data.

	I	II	III	IV	
	8/26/1985	8/13/1986	8/14/1986	8/15/0986	
Node	UIF (cfs)				Demand (cfs) in Aug
Montezuma (outflow)	774	774	774	774	0*
Albany	193	0	0	0	352
Newton	256	178	195	189	67
Milford	283	328	393	326	134
Bainbridge	677	686	583	671	263
sum	2182	1966	1945	1960	816
Simulated Flow	1366	1150	1129	1144	
Flow regime target (cfs)	2424	2368	2506	2325	
Flow gap	1058	1218	1377	1181	
Flow gap due to diversion (cfs)	242	402	561	365	
Flow gap due to water use (cfs)	816	816	816	816	

*The demand at Montezuma is included in the diversion at Montezuma.

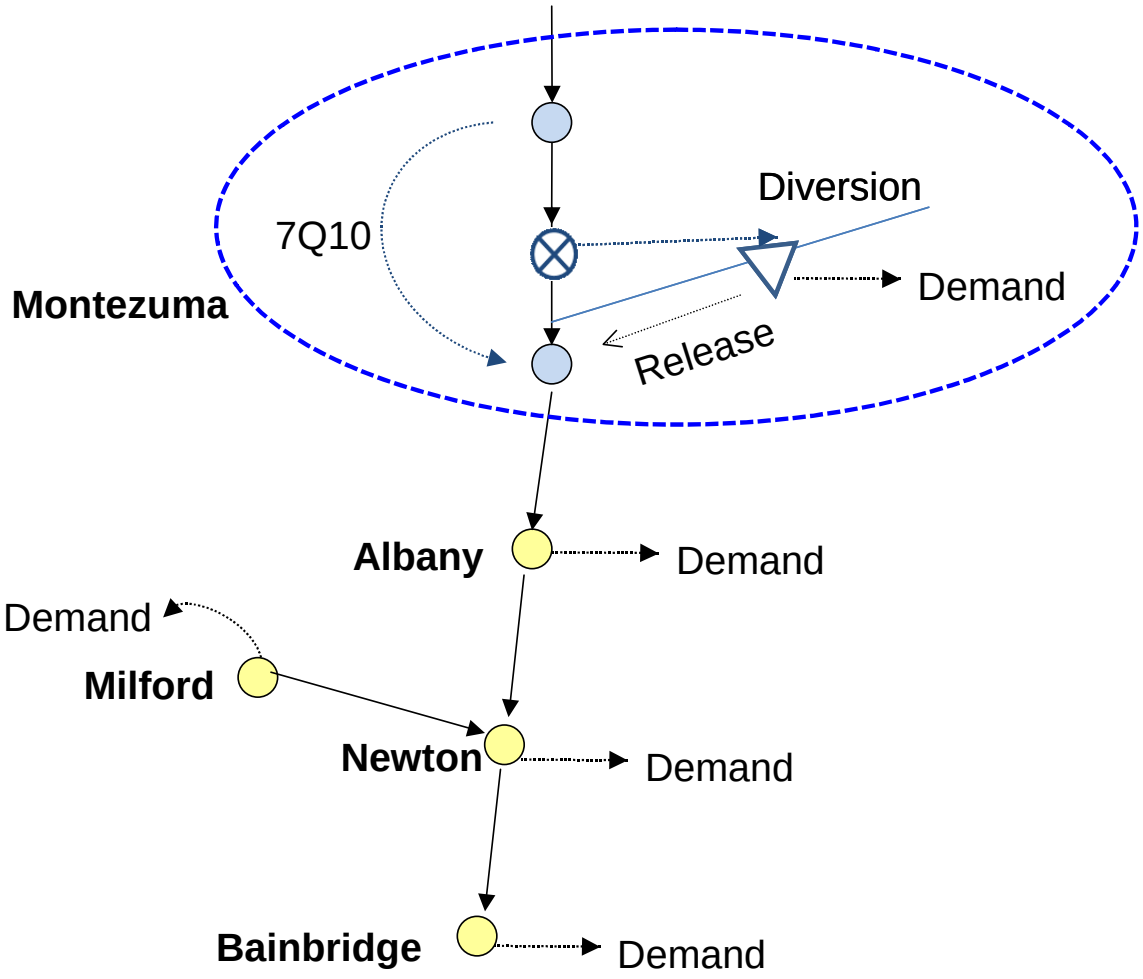

Figure 1. Schematic of the nodes.

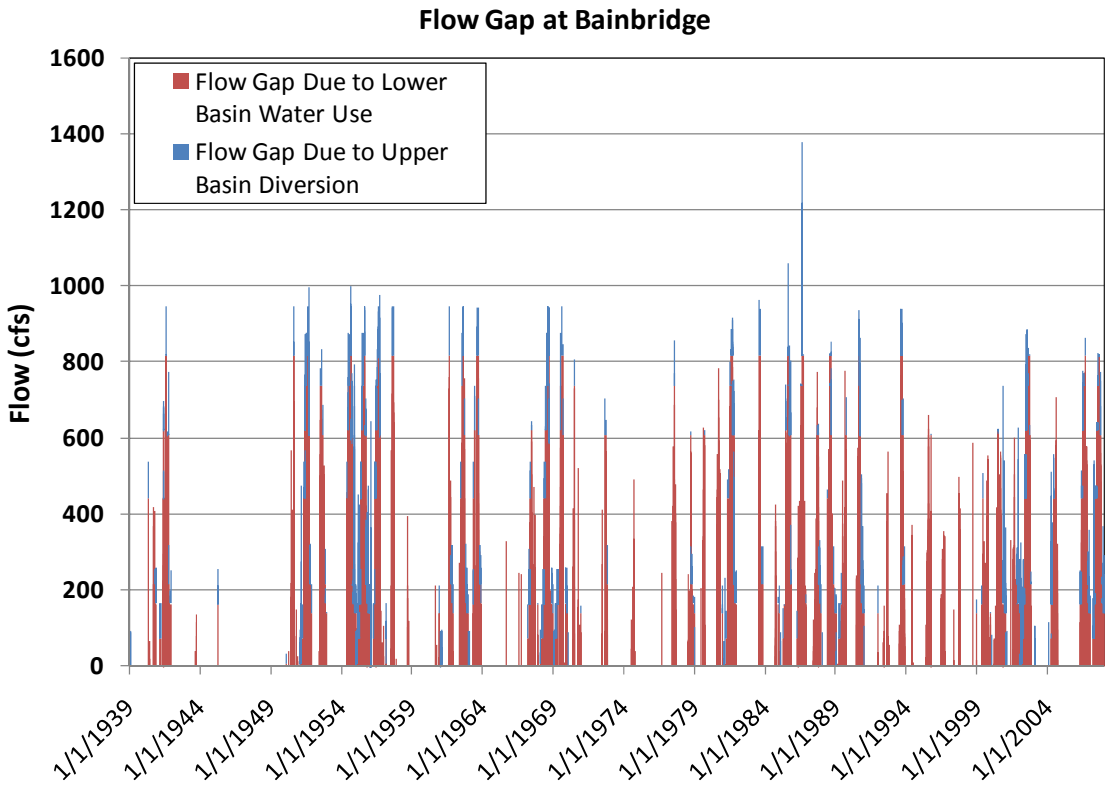

Figure 2. Flow gap components at Bainbridge from 1939 to 2007.

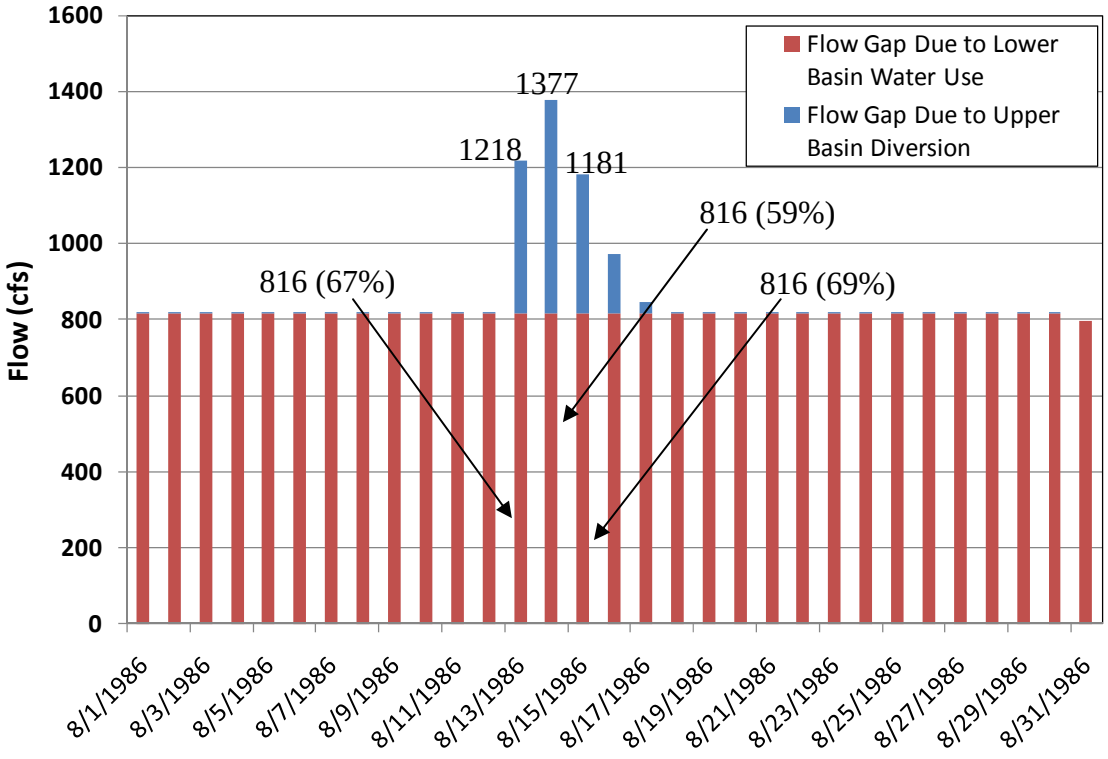

Figure 3. Flow gap components at Bainbridge in August 1986.

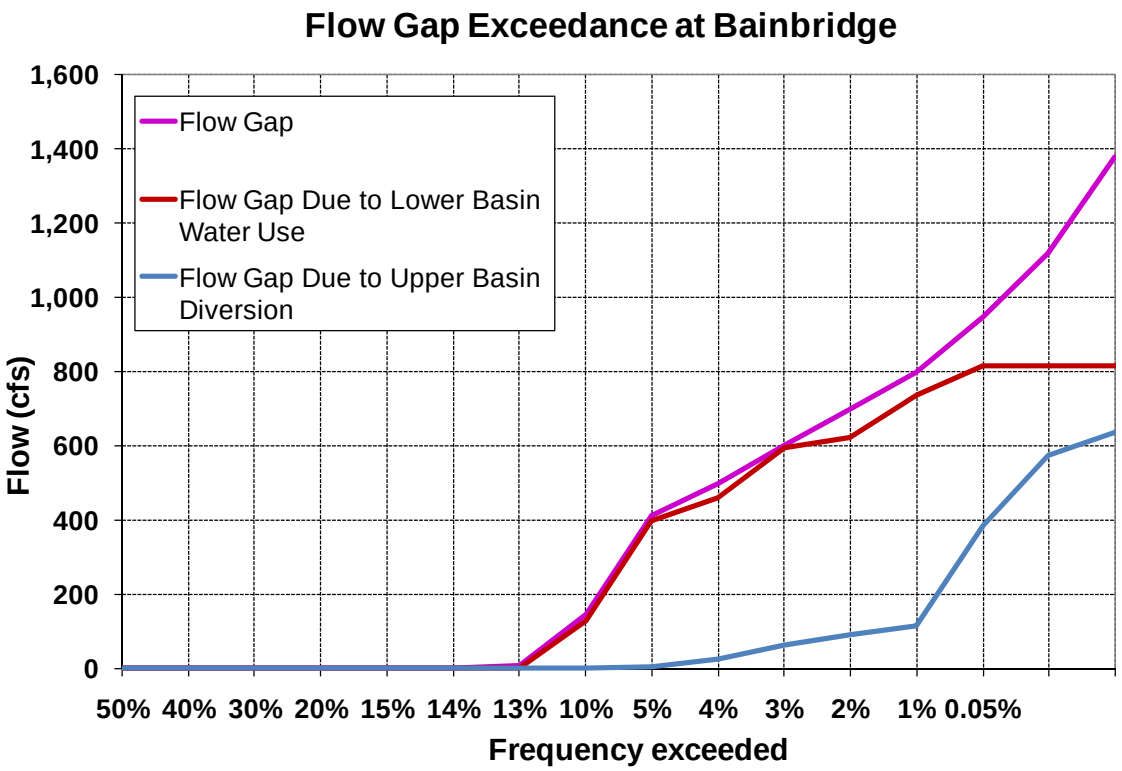

Figure 4. Frequency of flow gap at Bainbridge from 1939 to 2007.