Memorandum

To: Stan Murphy, Manager – Republican River Water Conservation District

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Date: February 20, 2007

Subject: Preliminary – Benefits to Colorado's Compact Compliance of Draining Bonny Reservoir

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This memorandum provides our preliminary analysis to summarize the effect on the Republican River compact accounting if Bonny Reservoir is drained. In general, the three benefits from emptying Bonny Reservoir in terms of compact compliance are:

1. The reduction in consumptive use due to less reservoir evaporation losses.
2. Removal of groundwater depletions due to seepage from Bonny Reservoir into the Ogallala Aquifer.
3. The reduction in groundwater pumping impacts as the result of removing the re-timing effect of Bonny Reservoir on groundwater inflows into the reservoir.

The following sections give a general background on historical operation of Bonny Reservoir and discuss the impacts from each of the above items on compact compliance accounting. Figure 1 is a map showing the location of Bonny Reservoir and the pertinent streamflow gage locations.

BACKGROUND

Bonny Reservoir was originally constructed by the United States Bureau of Reclamation as part of the St. Francis Unit. The St. Francis Unit was planned to supply irrigation water to approximately 6,000 acres of land that was not irrigated in the 1930's. This land would be served by using the Armel Pump to lift the water out of the South Fork up to irrigate lands on the terrace northeast of Bonny. The Armel Pump lift was never constructed. Substantial benefits were also anticipated from Bonny Reservoir as the result of flood protection, fish and wildlife conservation, recreation, and a supplemental irrigation supply for an existing 750 acres under the Hale Ditch.

Bonny Reservoir became a Colorado State Park in 1966. Historically, a portion of the yield from Bonny Reservoir was sold to out-of-state industrial users in the 1960's and 1970's. It was the sale of this water that lead to the Division of Wildlife applying for a water right at Bonny Reservoir in 1977 ("Bonny Reservoir Operating Plan", Colorado Water Conservation Board, July 1979).

The crest of the spillway at Bonny Reservoir is at an elevation of 3,710 feet which corresponds to a capacity of 170,100 ac-ft. The top of the active conservation storage pool is at

elevation of 3,672 feet which corresponds to a capacity of 41,300 ac-ft. The 128,800 ac-ft of storage between the top of the conservation pool and the spillway crest elevation is dedicated for flood protection. The dead pool in the reservoir (i.e. the content below the lowest reservoir outlet) was determined to be 1,400 ac-ft when construction was completed at the reservoir in 1951. Because of sedimentation in the reservoir the dead pool is probably significantly smaller today.

Figure 2 is a graph of the historical reservoir elevation and Figure 3 is the historical reservoir contents in Bonny Reservoir for the period of 1986 to 2006. As shown in Figure 3, the reservoir content in Bonny Reservoir decreased about 2,500 ac-ft per year over the last 10 years. If this rate continues, then Bonny Reservoir will be dry in 4 or 5 years.

Bonny Reservoir inundated the original Hale Ditch diversion dam, so an outlet works was created in Bonny Dam to release water to the Hale Ditch. The Hale Ditch diversions averaged 2,100 ac-ft/yr for the 1950 to 2005 period. There have been no releases to the Hale Ditch since 2001. Currently the Division of Wildlife owns the majority of the interests in the Hale Ditch.

The streamflows in the South Fork have steadily declined since the 1950's as shown in Figure 4. There currently is not a gaging station located above or below Bonny Reservoir to measure the inflow and releases from Bonny Reservoir. From limited streamflow gaging information and interviews with the local water commissioner, the seepage from Bonny Reservoir Dam to the South Fork is estimated to be relatively constant year round in the range of 7 to 10 cfs.

RESERVOIR EVAPORATION

The amount of reservoir evaporation from Bonny Reservoir varied historically based on climatic conditions and reservoir contents. The historical net reservoir evaporation loss rate is about 3.5 feet/year (Net Evaporation = Lake Evaporation minus Effective Precipitation). The Colorado State Parks reports a water surface recreation area of 1,836 acres which corresponds to a capacity of about 35,000 ac-ft. From 1952 to 1996 the historical reservoir evaporation losses on Bonny Reservoir average approximately 5,000 ac-ft/yr. The reservoir evaporation loss in 2005 has decreased to approximately 3,400 ac-ft/yr. The reservoir surface area in 2005 was 960 acres. Based on the stage-area-capacity survey from 1951, the surface area is 240 acres at the dead the storage level of 1,400 ac-ft. As outlined earlier, the current dead storage volume is probably less due to sedimentation.

The long term benefit to Colorado of eliminating the Bonny Reservoir evaporation losses is not the 3,400 ac-ft/yr of reservoir evaporation losses. The net benefit also needs to account for the decrease in the virgin flow water supply as the result of removing 3,400 ac-ft/yr from the compact accounting. Colorado is entitled to 44.4% of the virgin water supply on South Fork. If the virgin water supply is reduced, then Colorado's compact entitlement is reduced. The water currently lost to reservoir evaporation at Bonny Reservoir currently counts toward the virgin water supply calculations, but would probably not reach the Benkleman gage accounting station if Bonny Reservoir was drained and the evaporation losses were left in the stream. Therefore, the net improvement in compact compliance is the reduction in Colorado's consumptive use

minus Colorado's reduced compact entitlement for a net benefit of approximately 1,900 ac-ft/yr (1,900=3,400 - .444 x 3,400).

A one-time benefit to Colorado is possible by releasing the remaining storage in Bonny Reservoir and this release reaching the compact accounting station at Benkleman approximately 50 miles downstream. As of January of 2007, approximately 8,500 ac-ft could be released from Bonny Reservoir. In January of 2007 the flow at the stateline gage was about 7 cfs but the flow at the Benkleman gage accounting station is zero. There has not been any measured streamflow at the Benkleman gage since May of 2003. In July of 2005 a major rainfall event produced over 600 cfs for one day at the Stateline gage, but none of this water made it to the Benkleman gage. This indicates very large transit losses on any releases from Bonny Reservoir.

Colorado is entitled to 44.4% of the virgin flow generated in the South Fork Basin. The one-time benefit Colorado would receive from the release in Bonny Reservoir would be the amount of reservoir release that reached the Benkleman Gage multiplied by 44.4%. If the water was released in a slug over a one or two month period, it is possible that 50% of the water could reach the Benkleman gage. Therefore, the one-time benefit of draining Bonny Reservoir might be on the order of about 2,000 ac-ft (8,500 x .50 x .444). The estimate that 50% of the release could reach the Benkleman Gage is an estimate based on historical streamflow gages and engineering judgment. The actual value could be higher or lower.

GROUNDWATER ACCOUNTING

Colorado will receive two benefits from draining Bonny Reservoir as a result of the groundwater accounting in the Republican River Compact accounting. The first benefit is reduced seepage losses from Bonny Reservoir to the Ogallala Aquifer. The second benefit is the elimination of the re-timing of inflows into Bonny Reservoir.

In 2005, Colorado was charged 1,300 ac-ft of consumptive use as the result of Bonny Reservoir seepage to the Ogallala Aquifer. If Bonny Reservoir is drained, then this 1,300 ac-ft/yr of consumptive use is eliminated. Similar to the logic of eliminating the evaporation losses, the net benefit of reducing the seepage loss needs to account for the reduction in the virgin flow calculations. Therefore the net benefit to Colorado from eliminating Bonny Reservoir seepage losses is approximately 700 ac-ft/yr (700 = 1,300 – 1,300 x 0.444). The Bonny Reservoir seepage losses vary with groundwater levels in the Ogallala aquifer. The estimated net benefit of 700 ac-ft/yr will increase gradually each year into the future and in 50 years the net benefit will be approximately 1,000 ac-ft/yr.

The second benefit to draining Bonny Reservoir is the result of eliminating the re-timing effect of Bonny Reservoir. Currently the inflow to the reservoir is captured and then re-released downstream in a relatively constant pattern due to seepage under Bonny Dam. If Bonny Reservoir is drained, then the inflow that is currently stored would be passed directly through the reservoir. This is an advantage to Colorado because the water that is passed directly through Bonny Reservoir will experience a greater loss due to the phreatophytes growth between Bonny Reservoir and the Benkleman gage. The Bonny Reservoir inflow that is

currently being depleted by well pumping would be consumed by downstream phreatophytes if Bonny Reservoir was drained. As a result Colorado would not be charged for this loss in the compact accounting.

The groundwater model and the groundwater accounting procedures were used to analyze the benefits of eliminating the re-timing of the inflows to Bonny Reservoir. Under 2005 conditions, the result is a reduction in the Colorado consumptive use by 4,000 ac-ft/yr. The net benefit needs to account for the change in virgin flow calculations. The net benefit to Colorado in terms of compact compliance from eliminating the re-timing effect from Bonny Reservoir is approximately 2,200 ac-ft/yr (2,200 = 4,000 – 4,000 x 0.444). The estimated net benefit of 2,200 ac-ft/yr will increase gradually each year into the future and in 50 years the net benefit will be approximately 3,100 ac-ft/yr.

SUMMARY

Draining Bonny Reservoir will improve Colorado's compact compliance by reducing evaporation losses, reducing the Bonny Reservoir seepage to the Ogallala aquifer, and reducing the effect of Bonny Reservoir re-timing the inflows to the reservoir. The net benefit to Colorado of the above three changes is 4,800 ac-ft/yr as summarized in the following table:

Net Effect of Draining Bonny Reservoir (values in ac-ft/yr)

Description	Reduced Consumptive Use	Colorado's Reduced Virgin Water Supply Allocation	Net Benefit to Colorado's Compact Compliance
Reservoir Evaporation	3,400	1,500	1,900
Seepage to Ogallala Aquifer	1,300	600	700
Groundwater Accounting	4,000	1,800	2,200
Total	**8,700**	**3,900**	**4,800**

The benefit of draining Bonny Reservoir will gradually increase as the groundwater conditions change and in 50 years the net benefit will grow to approximately 6,000 ac-ft/yr. The above analysis assumes that future runoff conditions in the South Fork basin will remain approximately the same as the 2005 conditions. In 2005 there was no streamflow on the Benkleman gage. Table 1 presents the detailed compact accounting under 2005 conditions with and without Bonny Reservoir.

The estimated one time benefit of draining 8,500 ac-ft of storage in Bonny Reservoir is estimated to be about 2,000 ac-ft/yr. The exact amount is difficult to estimate because the amount of transit loss between Bonny Reservoir and the Benkleman gage is very large. There has not been any flow at the Benkleman gage for almost 4 years.

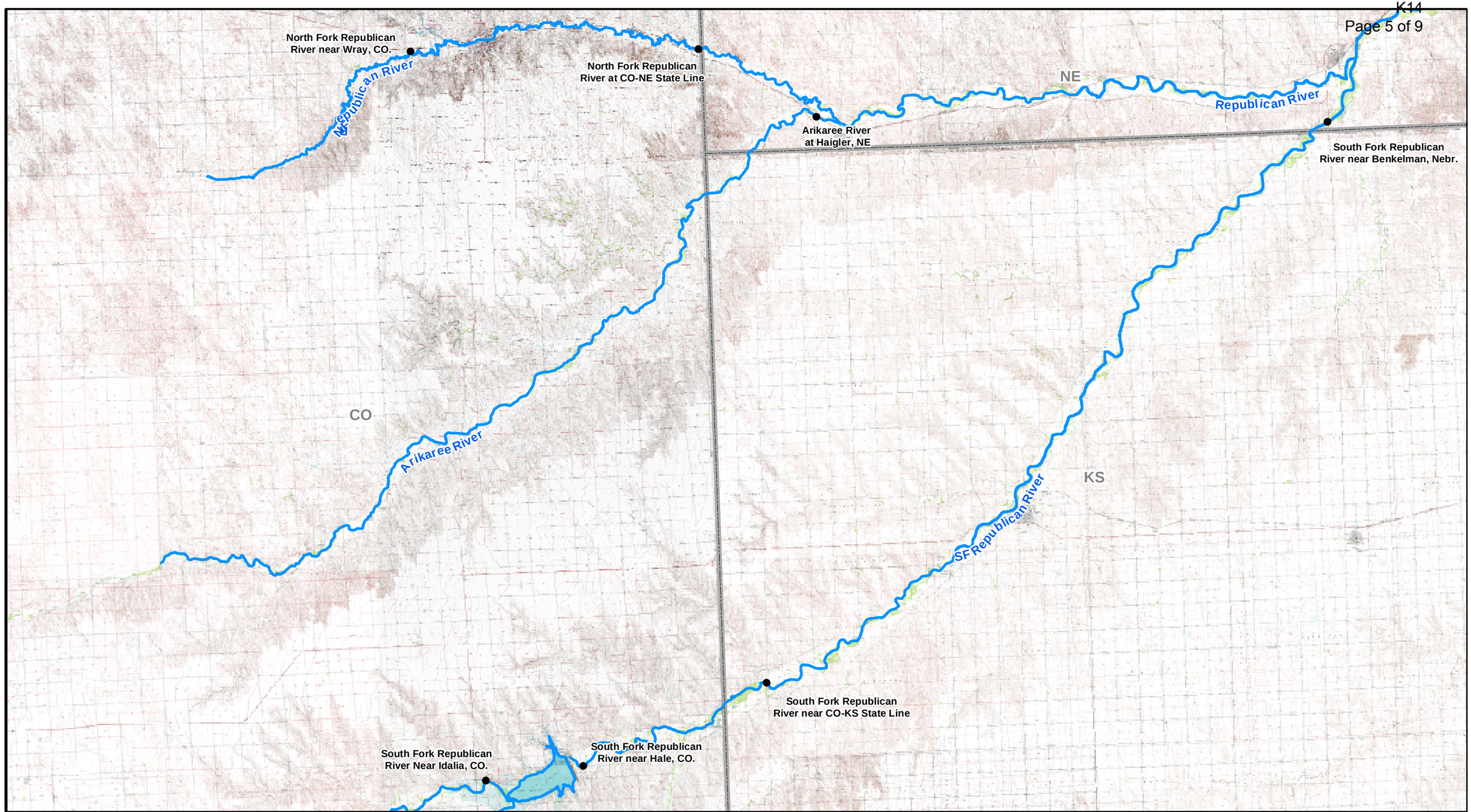

Figure 1

Location of Stream Gages
Republican River Basin

0 5 10 20
Miles

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Job No.
R1601

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Checked by:

Date: 2/19/2007

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Date:

Figure 2
Bonny Reservoir Surface Elevation

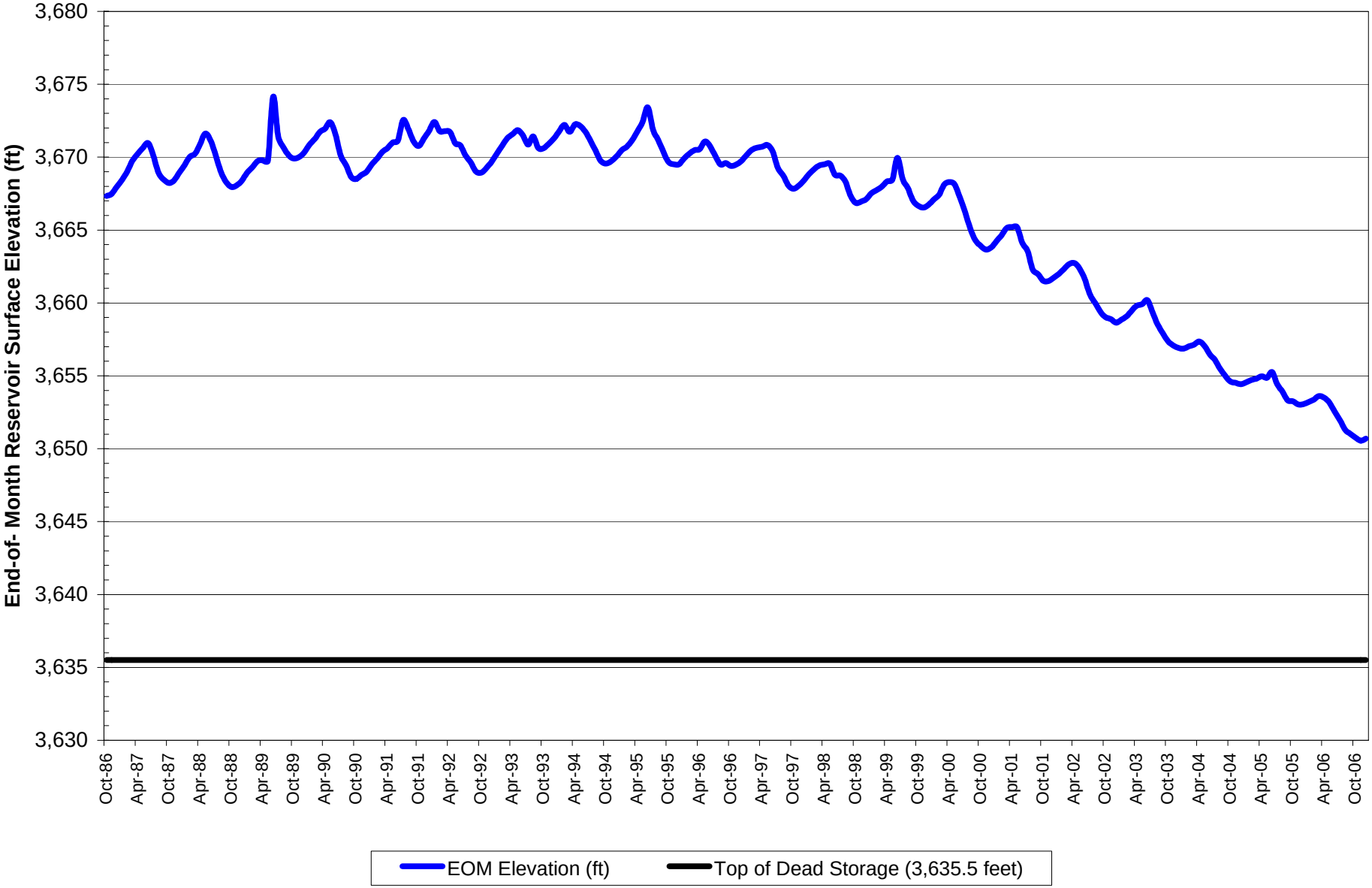

Figure 3
Bonny Reservoir Content

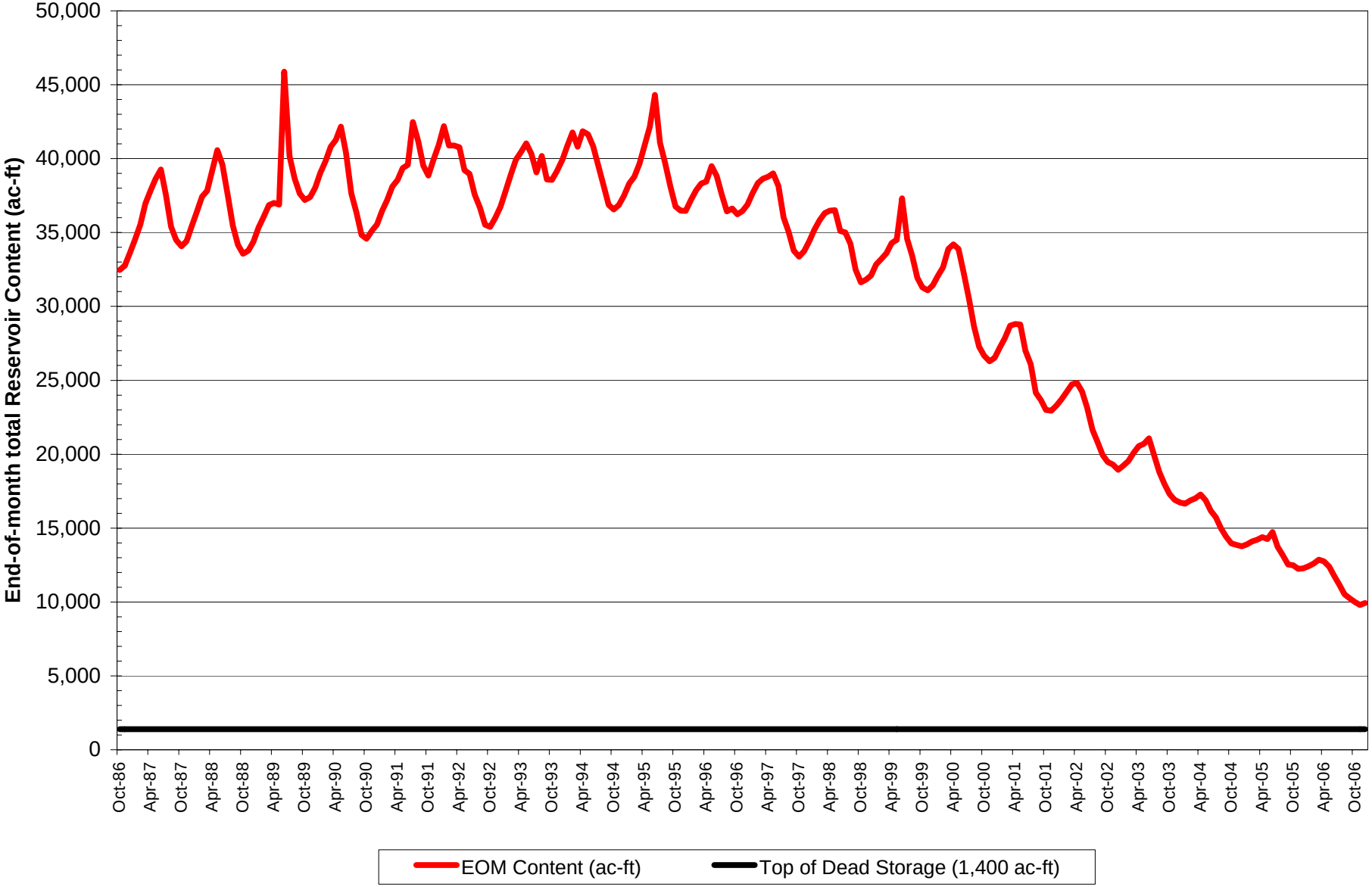

Figure 4
Stream Flows Gages on the South Fork of the Republican River

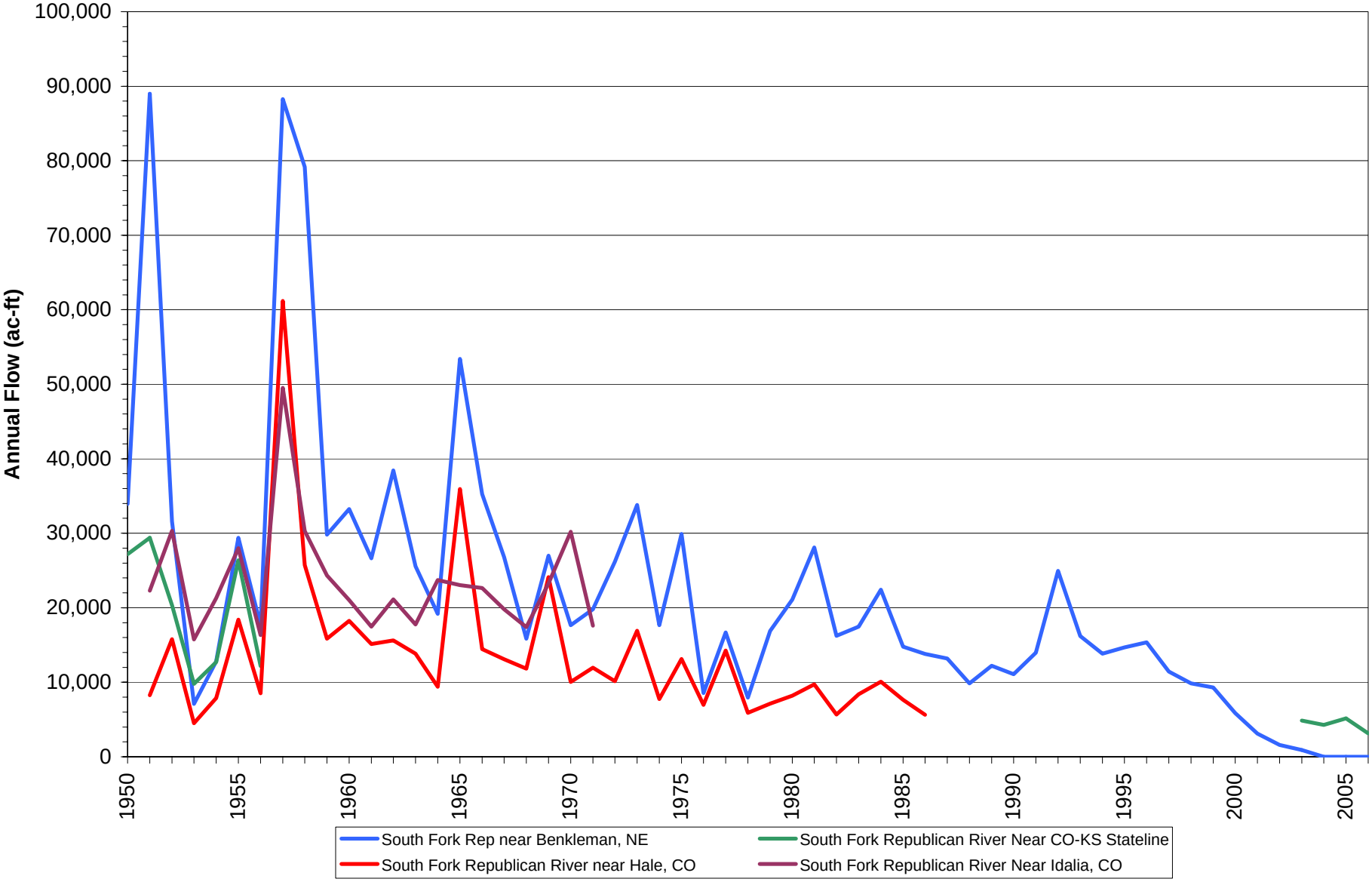

Table 1
2005 Republican River Basin Accounting
South Fork of the Republican River

Step 1 - Calculate Virgin Flow

Row	Description	Actual 2005 Accounting (ac-ft/yr)	Projected 2005 Accounting without Bonny Reservoir (ac-ft/yr)
(1)	(2)	(3)	(4)
(1)	South Fork Republican River Near Benkelman Gage	0	0
(2)	Nebraska Groundwater Depletions	1,372	1,372
(3)	Kansas Groundwater Depletions	7,227	7,227
(4)	Kansas Surface Water Consumptive Use	0	0
(5)	Kansas Non-Federal Reservoir Evaporation	285	280
(6)	Colorado Groundwater Depletions	14,952	**9,700**
(7)	Hale Ditch Consumptive Use	0	0
(8)	Colorado consumptive use from other small diversions.	275	275
(9)	Non-Federal Reservoir Evaporation.	0	0
(10)	Bonny Reservoir Evaporation	3,430	**0**
(11)	**Computed Basin Supply**	**27,541**	**18,854**

Step 2 - Determine Colorado's Allocation

Row	Description	ft/yr)	Amount (ac-ft/yr)
(12)	**Colorado Allocation is 44.4% of the Computed Basin Supply (calculated as Row 11 x .444)**	**12,230**	**8,370**

Step 3 - Sum Colorado's Consumptive Use

Row	Description	ft/yr)	Amount (ac-ft/yr)
(13)	Calculated as Total of Rows (6) through (10)	**18,657**	**9,975**

Step 4 - Amount Colorado Exceeded Compact Allocation

Row	Description	ft/yr)	Amount (ac-ft/yr)
(14)	**Difference (calculated as Row12 - Row13)**	**6,427**	**1,605**
(15)	**Net Benefit of draining Bonny Reservoir (difference in Row 14)**		**4,822**