Santa Fe River Studies

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Fate of Reservoir Releases

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This is one of a series of scientifically-based studies designed to provide the technical background information for decision makers and the community in evaluating management options for the Santa Fe River. The series covers the following topics: stream flow, storm flow, reservoir storage, ecosystem watershed yield analysis, stream flow losses, stream-aquifer interaction, and fate of reservoir releases. For more information on the series, please contact Claudia Borchert at 505-955-4203 or ciborchert@santafenm.gov

Santa Fe River Stream Studies: Fate of Reservoir Releases

A series of hypothetical hydrographs were developed for discussion based on a release of 1,000 acre-ft per year (ac-ft/yr) in order to develop a strategy for releasing Santa Fe River water from Nichols and McClure reservoirs for environmental flows in the reach below Nichols reservoir. An annual release of 1,000 ac-ft/yr is equivalent to 1.38 cubic-feet per second (cfs) below Nichols Reservoir if released year-round at a constant rate. For environmental flows, it may be more desirable to have water available to the riparian habitat during the growing season (April through September), rather than a lesser amount year-round. To examine some of the possible options for releasing the water, three release scenarios were initially developed:

A. Constant release during summer months of 2 cfs, with a late spring peak flow of 4.45 cfs in May

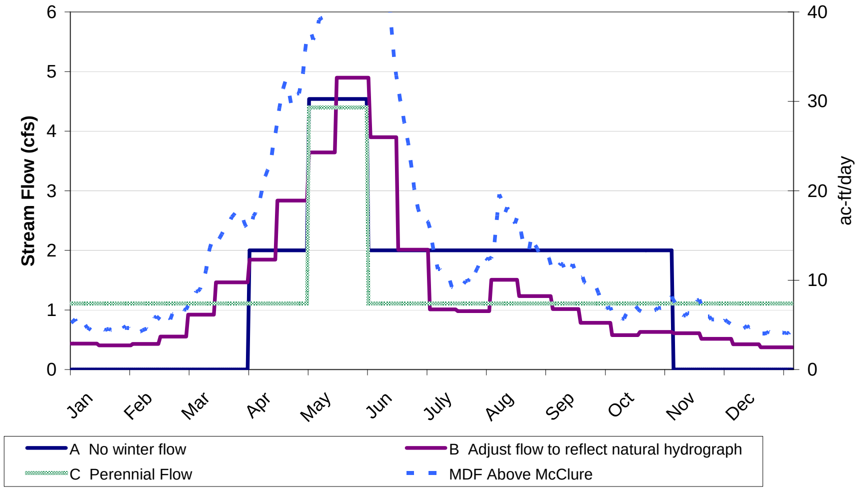
B. Perennial flow replicating shape of hydrograph of median daily inflow to McClure

C. Perennial flow of 1.11 cfs with a peak runoff of 4.3 cfs in May

Figure 1 shows the monthly pattern of releases for the three release scenarios. While Scenarios A and C are relatively straight forward, Scenario B was developed based on the pattern of natural inflow to the Santa Fe River. A release of 1,000 ac-ft per year represents about 18 percent of the average annual flow of 5,600 ac-ft/yr into McClure each year from 1966 through 2007 which is the period of record for which we have daily data. To replicate a release of 1,000 ac-ft/yr based on the shape of the mean daily inflow to McClure, the mean daily inflow was multiplied by 18 percent. A peak of 4.49 cfs at the *below Nichols* gage occurs in May under this scenario.

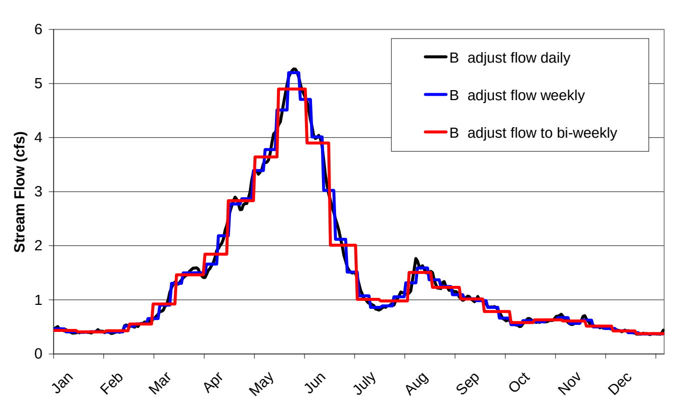
Note: For information on the stream gage locations see the report in this series titled "Stream Flow" (Lewis and Borchert, 2009a).

Figure 1. Hypothetical Hydrographs for the mean daily flow at the *below Nichols* gage on the Santa Fe River.



To determine how frequently the release would need to be adjusted for operational constraints (physically adjusting the outlet from Nichols reservoir is cumbersome and best only done only weekly, daily flows were compared to weekly and bi-weekly adjustments as shown in Figure 2. The bi-weekly adjustments in reservoir releases by water treatment plant personnel will be adequate to replicate the shape of a natural hydrograph.

Figure 2. Hypothetical hydrographs for the mean daily flow at the *below Nichols* gage under scenario B.



To estimate the fate of releasing 1,000 ac-ft/yr to the stream under each of these scenarios, the amount of water lost to seepage and evapotranspiration must be estimated. A portion of the water flowing down the Santa Fe River will seep into the ground, evaporate directly from the surface of the stream, or be consumed by vegetation and transpired to the atmosphere. Water released from Nichols Reservoir can also be diverted by acequias with rights to the river flow. The water that seeps into the ground can either migrate to the water table tens to hundreds of feet below the river bed or flow along a perched zone and reappear further downstream. A series of seepage studies have been conducted and are summarized in the Stream Flow Losses report (Lewis and Borchert, 2009b). None of these studies partition the infiltrated flow into the amount that recharges the aquifer (shallow or deep) or evapotranspirates to the atmosphere. However, the seepage studies do provide an estimate of the total losses and the expected distance that the surface water releases will travel downstream in the Santa Fe River.

The fate of a 1,000 ac-ft release was estimated using the relationship of seepage loss rates and flow at each gage on the upstream end of each of three reaches: 1) the *up-town* reach from the *below Nichols* gage to the *above St. Francis* 2) the mid-town reach from the *above St. Francis* gage to the *Ricardo* gage and 3) the west-side reach from the *Ricardo* gage to the wastewater treatment plant (WWTP).

For the up-town reach, which is 4.4 miles long, the flow at the *above St. Francis* gage was estimated by the following equations:

If flow is < 10 cfs, then flow at *above St. Francis* is:

$Q_{\text{St.Francis}} = Q_{\text{blw Nichls}} - (0.4\text{cfs/mile} * 4.4 \text{ miles})$

If flow if > 10 cfs, then flow at *above St Francis gage:*

$Q_{\text{St.Francis}} = Q_{\text{blw Nichls}} - ((0.0576 * Q_{\text{blw Nichls}}) \text{ cfs/mile} - 0.2716) * 4.4 \text{ miles})$

The seepage rates are based on seepage studies and analysis of gage data as explained in the Stream Flow Losses report. The flows below 1.8 cfs at the *below Nichols* gage do not reach the *above St. Francis* gage with a seepage rate of 0.4 cfs/mile over a 4.4 mile reach and thus, any release scenario with flows less than 1.8 cfs will only travel part way through town. The equation for flows above 10 cfs is based on the linear regression of winter seepage rates for days where flow at the upstream gage was continuous higher than the downstream gage for the entire day.

For the mid-town reach which is 1.6 miles long, the flow at *Ricardo* was estimated by the following equations:

If flow at *above St. Francis* < 10 cfs, then flow at *Ricardo* gage:

$Q_{\text{Ricardo}} = Q_{\text{St.Francis}} - ((0.4) \text{ cfs/mile}) * 1.6 \text{ miles})$

If flow at *above St. Francis* is > 10 cfs, then flow at *Ricardo* gage:

$Q_{\text{Ricardo}} = Q_{\text{St.Francis}} - ((0.8) \text{ cfs/mile}) * 1.6 \text{ miles})$

The seepage rates are based on seepage studies conducted in this reach as explained in Stream Flow Losses report. Flows below about 0.6 cfs at the *above St. Francis* gage do not reach the *Ricardo* gage assuming a seepage rate of 0.4 cfs/mile over the 1.6 mile long reach. However, the actual seepage rates may be as low as 0.1 cfs/mile and as high as 0.9 cfs/mile based on the range of seepage rates observed in seepage tests.

For the 7.3 mile long west-side reach, the flow at the WWTP was estimated by the following equations:

If flow at *Ricardo* gage < 10 cfs, then flow at WWTP:

$Q_{\text{WWTP}} = Q_{\text{Ricardo}} - ((0.4) \text{ cfs/mile}) * 7.3 \text{ miles})$

If flow at Ricardo gage is > 10 cfs, then flow at WWTP:

$Q_{\text{WWTP}} = Q_{\text{Ricardo}} - ((0.83) \text{ cfs/mile}) * 7.3 \text{ miles})$

The seepage rates are based on seepage studies conducted in this reach as explained in Lewis and Borchert, 2009. Flows below about 1.5 cfs at the *Ricardo* gage do not reach the WWTP assuming a seepage rate of 0.2 cfs/mile over the 7.3 mile long reach. The actual seepage rates may be as low as 0.1 cfs/mile and as high as

1.1 cfs/mile based on the range of seepage rates observed in seepage tests.

Using these relationships between flows and seepage rates, the fate of the hypothetical releases (scenarios A, B and C in Figure 1) was estimated as shown in Figures 3 through 5. In release scenarios A and C, water reaches the *above St. Francis* and *Ricardo* gages only during the peak runoff in May, with a very small flow (0.24 cfs) at St. Francis during the summer months under scenario A. Under Scenario B, water would reach St. Francis April through mid-June and Ricardo from Mid-May to mid-June.

Two additional scenarios for releasing 1,000 ac-ft/yr over the growing season were evaluated that would increase the distance that the flows would reach downstream. Surface water in these scenarios is released in pulses for one day per week under Scenario D and two days per week under Scenario E over the summer period (April through September). Peak flows could reach 8 and 6 cfs at the WWTP under scenarios D and E respectively. As shown in Figure 6, 19.4 cfs is released for one day in scenario D, resulting in a flow of 8.3 cfs at the WWTP. Under scenario E, 9.7 cfs is released (Figure 7) for two days and 6.3 cfs reaches the WWTP. Releasing water in pulses would have the benefit of providing water for riparian vegetation over a longer reach, thereby benefiting a larger area of the community.

While the hypothetical hydrographs for the 5 scenarios are based on the average estimate of seepage rates available for the flow release volumes, the range of seepage rates can vary by a factor of 3 to 5. The range of losses using the lowest and highest seepage rates are shown in Table 1 and illustrated in Figures 8 through 10. Taking the lowest seepage rate observed for the best case scenario and the highest seepage rate for the worst case scenario, provides a range of

Figure 3. Estimated flow at the *below Nichols* and *above St. Francis* gages under release scenario A.

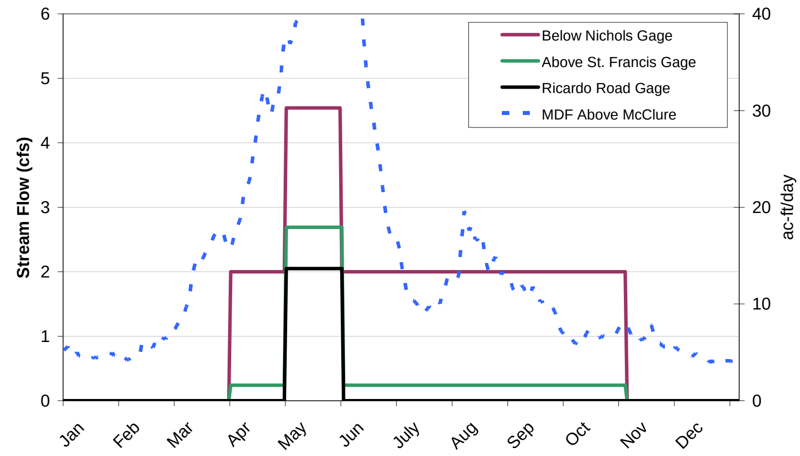


Figure 4. Estimated flow at the *below Nichols* and *above St. Francis* gages under release scenario B.

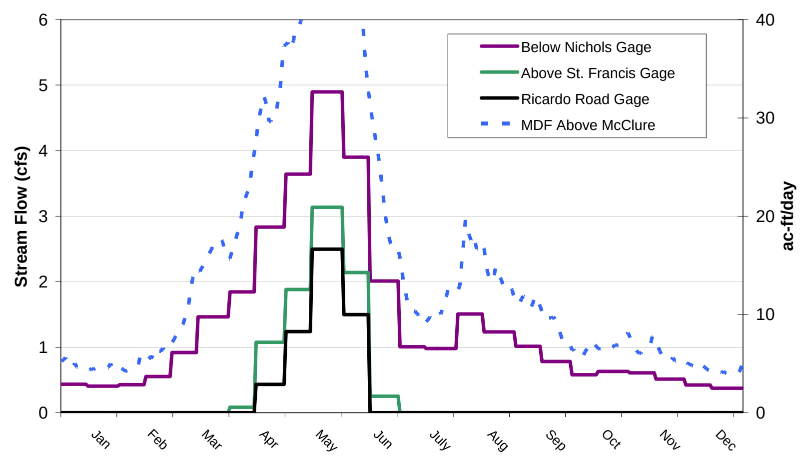
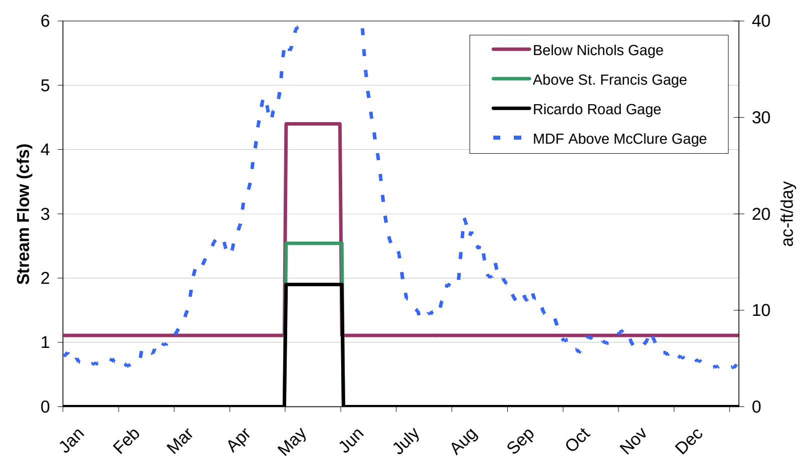


Figure 5. Estimated flow at the *below Nichols* and *above St. Francis* gages under release scenario C.



estimates in the ultimate fate of water released from Nichols Reservoir.

Table 1 summarizes the equations used in each of the estimates and Figures 8 through 10 show the range of flows for each of the scenarios at three different locations on the Santa Fe River. Under the *Best Case* conditions where the lowest seepage rate is used, water would reach the WWTP under all scenarios. However, under the *Worst Case* conditions where the highest seepage rates are used, water would only reach St. Francis Bridge under scenarios D and E.

Each of these scenarios not only varies in the timing of surface water flow, but also varies in the magnitude of infiltration of recharge to the City well field. The total volume of water lost to recharge or evapotranspiration within each reach using the average seepage rates is shown in Table 2. Under scenarios A and C, 86 to 87 percent of the total water released is lost in the up-town reach. In other words, only 13 to 14 percent flows past St. Francis Bridge. In each of the first 3 scenarios, about 94 percent is lost in the reach that would contribute to recharge in the vicinity of the City's wells field, which is the up-town and mid-town reaches. Scenarios D and E provide less than a third of the water potentially recharging to the city wells in scenarios A, B and C. Recharge to the groundwater may increase well production and longevity of the aquifer by mitigating the water level declines that have occurred over the past 50 years. The portion of water that is consumed by evapotranspiration has not been estimated.

Figure 6. Estimated flow at the *below Nichols* gage and the WWTP under release Scenario D.

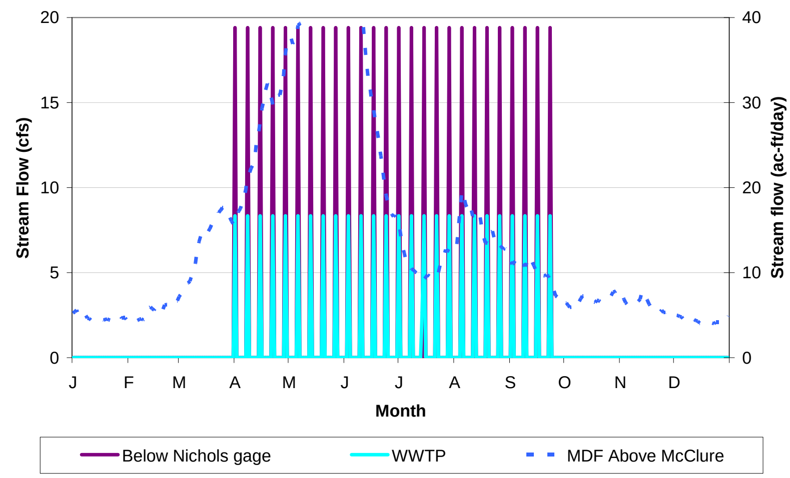


Figure 7. Estimated flow at the *below Nichols* gage and the WWTP under release scenario E.

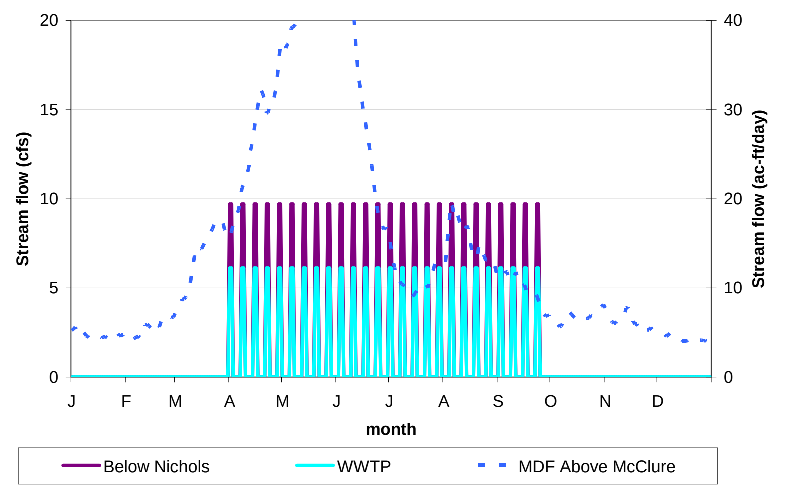


Table 1. Rules for estimating the flow on the Santa Fe River for each of the scenarios.

Condition	Up-town Reach (4.4 mi)	Mid-town Reach (1.6 mi)	West-side Reach (7.3 mi)
	Flow at *above St. Francis*	Flow at *Ricardo*	Flow at WWTP
Average Case*	Flows < 1.8 cfs at *below Nichols* gage do not reach *above St. Francis gage*, Flows between 1.8 and 10 cfs seep at 0.4 cfs/mi, Flows > 10 cfs lose at 0.0576Q-.2716 cfs/mi	Flows <1 cfs at *above St. Francis* gage do not reach *Ricardo* gage, Flows > 1 cfs and < 10 cfs lose at 0.4 cfs/mi Flows > 10 cfs lose at 0.6 cfs/mi	Flows <1.5 cfs at *Ricardo* gage do not reach the WWTP, Flows > 1.5 to 10 cfs lose at 0.2 cfs/mi Flows > 10 cfs lose at 0.8 cfs/mi
Best Case	Flows less than 1.3 cfs at *below Nichols gage* do not reach *above St. Francis* gage, Flows > 1.3 cfs seep at 0.3 cfs/mi.	Flows <0.5 cfs at *above St. Francis* do not reach *Ricardo* gage, Flows > 0.5 cfs lose at 0.3 cfs/mi	Flows <1 cfs at *Ricardo* gage do not reach WWTP Flows >1 cfs lose at 0.13 cfs/mi
Worst Case	Flows less than 5 cfs at *below Nichols* gage do not reach *above St. Francis* gage, Flows > 5 cfs seep at 1.2 cfs/mi.	Flows <1.6 cfs at *above St. Francis* gage do not reach *Ricardo* gage, Flows > 1.6 cfs lose at 1.0 cfs/mi	Flows <7 cfs at *Ricardo* gage do not reach WWTP, Flows > 7 cfs lose at 1.1 cfs/mi

***Average case is based on average seepage rates from seepage studies performed on flows less than 10 cfs.

Table 2. Stream flow losses by reach for each scenario of releasing 1,000 ac-ft/year.

Reach	**A**	**B**	**C**	**D**	**E**
	ac-ft/yr	ac-ft/yr	ac-ft/yr	ac-ft/yr	ac-ft/yr
Up-town Reach	747	738	844	192	130
Mid-town Reach	146	126	59	74	99
West-side Reach	92	112	92	278	154
All Reaches	985	977	995	544	383
Reaches Benefiting City Well Field*	893	865	903	266	229

* Defined as the up-town and mid-town reaches

Figure 8. Peak flow in the Santa Fe River at the above St. Francis Bridge gage under five release scenarios.

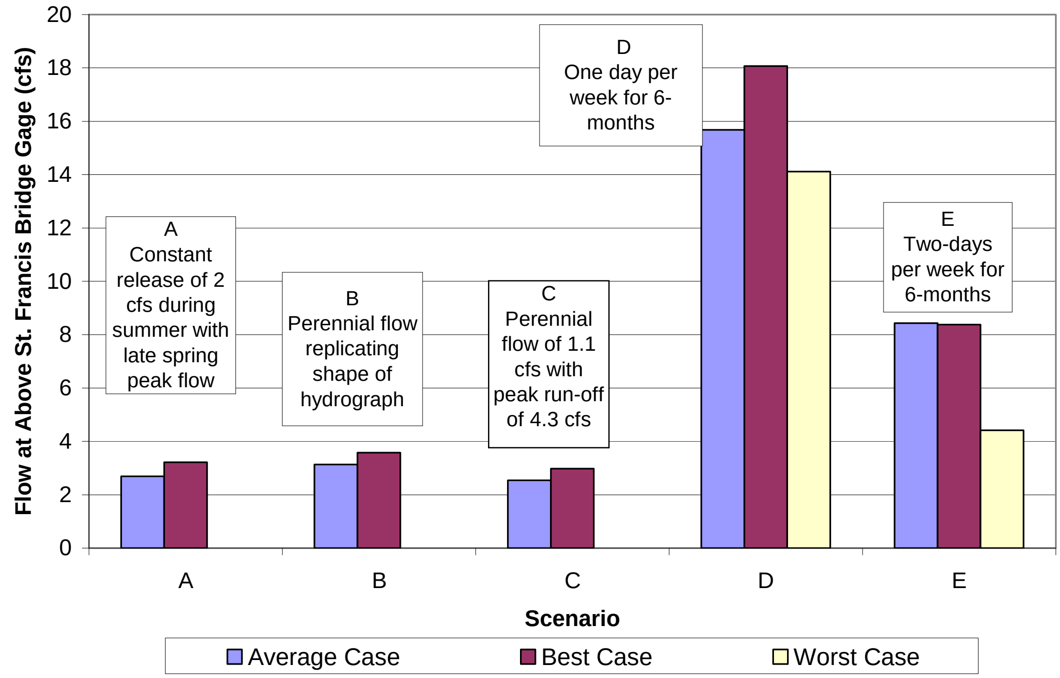


Figure 9. Peak flow in the Santa Fe River at the Ricardo gage under five release scenarios.

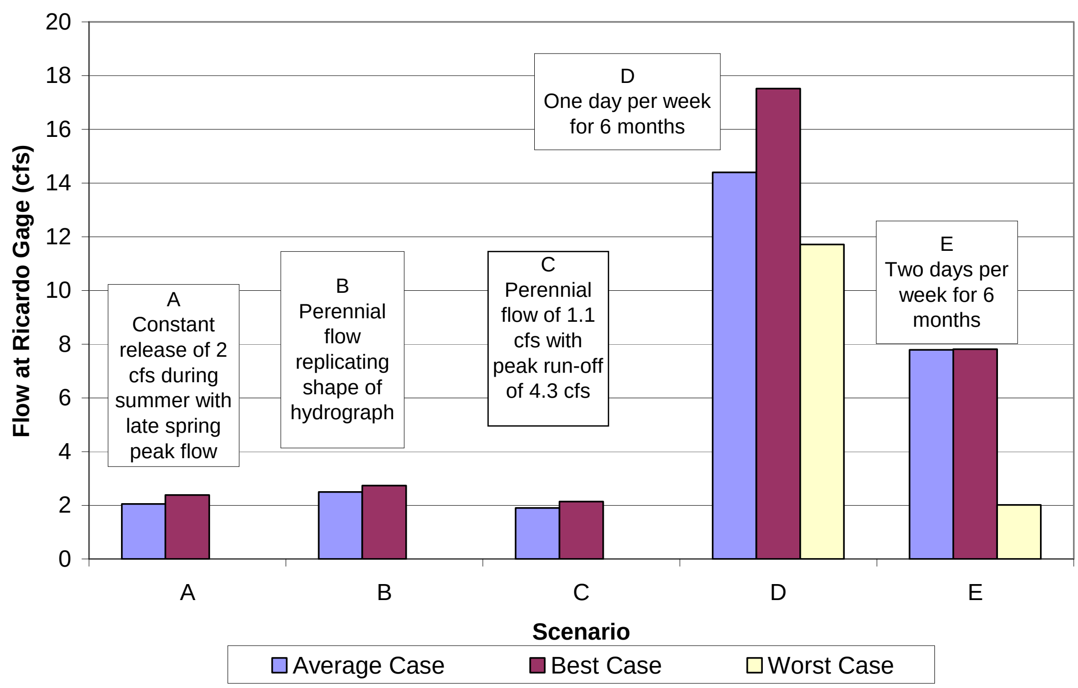
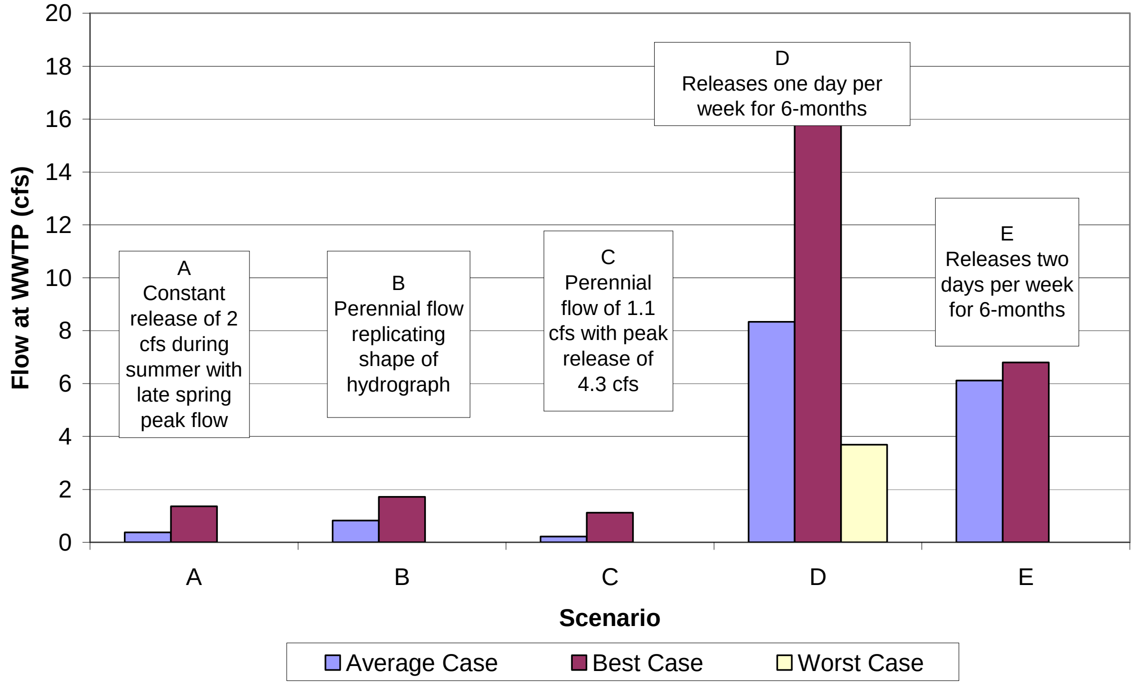


Figure 10. Peak flow in the Santa Fe River at the WWTP under five release scenarios.



References

Lewis, Amy and Claudia Borchert. 2009a. Santa Fe River Studies: Stream Flow.

Lewis, Amy and Claudia Borchert. 2009b. Santa Fe River Studies: Stream Flow Losses.