Draft

Potential Effects of Colorado's Future Water Development on Central Platte River Peak Flows.

Prepared by:

Hydrosphere Resource Consultants, Inc.

(DRAFT) Potential Effects of Colorado's Future Water Development
on Central Platte River Peak Flows.

Introduction

As part of the Platte River EIS, there is a need to understand how potential water development to serve future municipal and industrial growth in the South Platte basin of Colorado might affect the timing, frequency, and magnitude of peak flow events in critical habitat reaches of the Central Platte River.

Peak flows are an important aspect of fluvial geomorphology and riparian ecology and may be critical for maintaining river health and endangered species habitat in the Platte River. Peak flows are the major cause of habitat forming and maintenance events; bed-load and sediment transport, riparian scouring and regeneration, and bar and dune formation all are functions of peaking river flows.

This analysis was undertaken to assess the potential impacts of Colorado's future water development on peak flows in the Central Platte River under a representative worst case scenario.

Background

The scope of analysis of the potential effects of Colorado's future water development on South Platte peak flows can be reduced considerably because of several practical realities.

Peak flows in the Central Platte may originate from the North Platte basin, the South Platte basin, from local drainages, or from a combination of the three. M&I water development in the South Platte basin of Colorado would affect only those peak flows during which substantial contributions came from the South Platte basin, and particularly from that part of the South Platte basin located upstream of the Kersey gage, simply because that is where the vast majority of the basin's population growth and associated water development is likely to occur.

Colorado water providers have developed a wide range of projects to meet their needs including surface diversions, reservoirs, tunnels, pipelines, wells and treatment plants. They have also relied on a variety of nonstructural measures including exchanges and plans of augmentation, water right acquisitions and water conservation programs. These projects and nonstructural measures reflect one or more of the following six basic water development strategies: transbasin water importation, nontributary groundwater development, conversion of in-basin irrigation rights, water conservation, water reuse, and diversion of South Platte native flows[1].

Of these six strategies, only South Platte native flow diversion and water reuse have the inherent potential to significantly reduce Central Platte River peak flows. Transbasin imports and nontributary groundwater development add water to the South Platte basin. Colorado's water laws assure that conversion of in-basin irrigation rights is done in a manner that maintains existing downstream flow regimes. Water conservation generally has no significant effect on stream flows.

Future projects that divert South Platte native flows can generally do so only during periods when unappropriated water is available (i.e. when all other senior water rights are satisfied). Because the South Platte basin is already heavily appropriated, this generally occurs only during the months of April through July of relatively wet years. At other times, the entire flow of the South Platte basin is diverted and rediverted by numerous existing water rights in the basin. There are also times and locations during the non-irrigation season (November through March) when unappropriated water is available, but these times generally don't coincide with occurrence of peak flows in the Central Platte.

[1] Two other strategies being considered include yield enhancement via vegetation management and cloud seeding. These strategies would not inherently impact Central Platte peak flows as reflected in historical conditions, and are therefore not addressed in this analysis.

Water reuse strategies are based on that aspect of Colorado water law that allows for use to extinction of: (a) 'foreign' water (water not part of a basin's native surface flow, such as transbasin water and nontributary groundwater); (b) the historically consumed portion of water rights that have been changed from a previously decreed use; and (c) in-basin water rights that have been explicitly decreed for reuse to extinction. These three types of water supply sources are generally referred to as reusable sources.

A single municipal use of water typically results in the majority of that water returning to the stream in the forms of wastewater and lawn irrigation return flows (LIRFs). Wastewater and LIRFs generated from reusable sources are collectively referred to as reusable return flows (RRFs), which are themselves reusable. RRFs are the property of the providers from whose water rights they are derived. Most providers with reusable sources are using some of their RRFs via exchanges and augmentation plans or by direct reuse. However, while providers generally plan to fully use their RRFs to extinction, most of them are not yet doing so, and unused RRFs are currently being diverted by downstream irrigation ditches, reservoirs and recharge projects[2].

Future projects involving water reuse will rely on currently unused RRFs as well as additional RRFs generated from future increases in reusable sources. RRFs are generated at relatively low and steady rates as a result of providers' first use of reusable sources. Consequently RRFs do not constitute a major portion of the South Platte's peak flow regime. The major potential effects of providers' future reuse strategies upon peak flows would therefore not be due to the immediate depletive effect of reuse (although this component is included in the analysis). Instead, the larger potential impact would be due to the potential 'rebound effect' of the resulting diminished supply of RRFs to downstream reservoirs, which may then divert more water during peak flow periods.

---

[2] It should be noted that these downstream diverters generally do not have a right to the continued availability of these unused RRFs; even though they may temporarily benefit from their availability. In fact several providers currently lease the right to divert their unused RRFs.

Study Approach

This study was conducted in four steps. First we identified the peak 1-day, 3-day and 30-day flow events that historically occurred during February through July of each year from 1947 through 1994 on the Platte River near Overton, and the corresponding flows on the South Platte at Julesburg and near Kersey considering travel times.

Next, we formulated and analyzed a 'representative worst case scenario' with respect to potential effects of Colorado's future water development upon South Platte peak flows. From this analysis, we estimated flow reductions near Kersey and at Julesburg for the identified 1-day, 3-day and 30-day flow events.

Then we addressed attenuation factors below Julesburg that would serve to reduce these potential impacts. Finally, as an addition to the 1, 3, and 30-day analysis, we extended the data to include all days within the historical period of record (1947-1994). This final analysis step is considered quite important due to the somewhat arbitrary selection of peak flow periods, and the fact that there may be multiple important peak flow events within a given year. Each of these steps is described in more detail below.

Identification of Historical Peak Flow Events

We collected daily gage data for water years 1947-1994 from the gages at Overton, Julesburg, Balzac and Kersey. Using these data, we identified the annual 1-day, 3-day, and 30-day peak events at the Overton gage based on daily average flows for the period February through July of each year. It should be noted that this identification process did not take into account the biological or fluvial geomorphologic significance of peak flows, it was based simply on hydrologic data.

We estimated the travel time between Kersey and Overton during peak flow events by correlating the Kersey gage data to peak events at Overton. We did this by analyzing the entire 48-year period of record and extracting peak flow events from both gages that were visually (subjectively) highly correlated. From these data, we estimated travel times from Kersey to Overton (Figure 1). Clearly there is an expected trend towards shorter travel times at higher flows. However, due to the highly manipulated nature of the river through the study area, and because we do not have a hydrodynamic model, relationships between flow and travel time are quite difficult to generalize to all peak flow events. To be consistent across the analysis, we therefore used the average travel time of 10 days from Kersey to Overton for all flow analyses. Additionally, the Nebraska point flow analysis used the lag times between gages as shown in Table 1 below. These lag values were estimated visually from gage data and distance between gages, rounded to the nearest day.

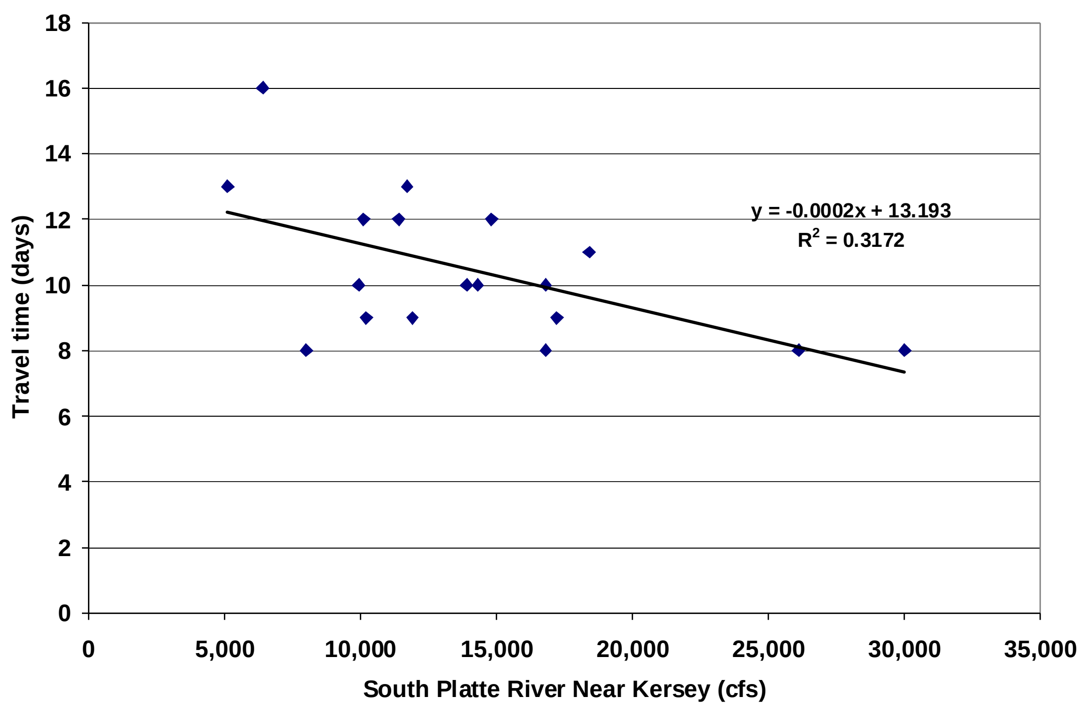

Figure 1: Correlation of travel time, Kersey to Overton, to peak flow events at Kersey.

Table 1. Travel times between gages.

Point Flow Location	Travel Time to Overton
South Platte at Kersey	10 days
South Platte at Balzac	8 days
South Platte at Julesburg	5 days
South Platte below Korty Diversion	4 days
South Platte at North Platte	3 days
Lake McConaughy / Keystone Diversion	4 days
Tri-County Canal / Central Diversion	2 days
Platte River at Brady	2 days
Platte River at Cozad	1 day

Representative Worst Case Scenario

Water providers in the South Platte basin are likely to continue to employ all six strategies described above in meeting their future needs. The resulting combined effects on peak flows would depend on the specific combination, size, location and timing of strategies employed. Rather than attempting to analyze a specific list of 'most likely' projects, this study examined a representative worst-case scenario in terms of impacts to Central Platte peak flows by analyzing a set of five hypothetical water development components that would deplete South Platte flows. These include:

- A major on-stream reservoir on the South Platte upstream of Denver
- An expanded Northern Integrated Supply Project involving a major on-stream reservoir on the Cache La Poudre River
- A major diversion project on the South Platte below Greeley serving metro Denver area providers
- Development of multiple reservoirs on South Platte tributaries, and
- Reuse to extinction of all historically unused RRFs from the metro Denver area.

Evaluated together, the aggregate impact of these five scenario components provides a representative estimate of worst-case impacts upon the Central Platte's historical peak flow regime from potential future water development in Colorado's South Platte basin[3].

Descriptions of each of the hypothetical water development components are provided below. These hypothetical project components are intended to represent a "worst-case" development scenario with respect to their impacts on peak flows, and to be representative of the potential range of actual projects in terms of their spatial and temporal impacts to peak flows. For each hypothetical project component, we provide a brief description of source data and methodology used to evaluate its potential impact on peak flows.

We assumed that the impacts of the individual scenario components were cumulative (i.e., diversion of water by one project would not necessarily impact water availability of other projects). The cumulative impact of the scenario components

[3] The only other category of water development option that would significantly increase impacts to peak flows would be a large on-stream reservoir on the mainstem of the South Platte below the confluence of its major tributaries. While such a project (Narrows Reservoir) was once proposed in the 1970s, the likelihood of such a project ever being developed is remote, given the project's extensive environmental and socioeconomic impacts, its relatively distant and downstream location relative to M&I water demands, its significant geotechnical problems and it high construction costs.

provided an initial estimate of the potential total reduction in flows at Kersey. This initial estimate was then subject to water availability and flow attenuation constraints as described in later sections of this report.

The 'worst case' nature of this scenario is illustrated by the fact that the combined water supply associated with the components included within this scenario would be in excess of 350,000 acre-feet per year, equivalent to the needs of more than 1,600,000 additional people within the South Platte basin. This supply would be in addition to any new supplies developed via transbasin imports, conversion of irrigation rights, water conservation or nontributary groundwater development.

DISCLAIMER: Any mention of specific water providers in the following descriptions is not intended to imply that the provider is actually proposing these projects as described in the analysis; they are used here as hypothetical examples only. It should also be noted that the technical, institutional and economic feasibility of such projects and their associated environmental and socioeconomic impacts have not been considered in this analysis.

Component 1: Major On-Stream South Platte Reservoir Above Denver

Metro Denver area providers are considering a variety of water development options to meet their future needs. Many options would involve projects or operations that would not affect South Platte peak flows, such as additional transbasin imports, nontributary groundwater development, conversion of irrigation rights and water reuse.

However, there are several projects being considered that would capture portions of South Platte peak flows originating upstream of or within the metropolitan Denver area. These include enlargements of Antero and Eleven Mile Reservoirs, reallocation of a portion of Chatfield Reservoir flood control storage to water supply purposes, development of off-channel gravel pit reservoirs, and new municipal diversions from Chatfield Reservoir. Also under discussion is a regional conjunctive use project between

Douglas County providers and Denver Water that would use Denver's existing reservoirs to store South Platte and Blue River peak flows and deliver surface water to Douglas County providers via a new pipeline.

All of these projects could capture a portion of South Platte peak flows. However, the combined depletive effect of these projects would not be as great as what would occur from a major new South Platte on-stream reservoir. In order to represent a worst case of South Platte native flow development upstream of Denver, we evaluated a hypothetical 400,000 acre-foot on-stream reservoir at the confluence of the South Platte and its North Fork. In our analysis we made the following assumptions about this reservoir:

1. It would capture only native runoff. This assumption is conservative in estimating South Platte peak flow impacts, because any such project would probably also rely on increased utilization of transbasin waters imported via the Roberts Tunnel or the Otero pump station.

2. For simplicity's sake, the reservoir was operated to provide deliveries according to a typical municipal demand curve, assuming that the project would serve as an exclusive water supply to a municipal water provider. In reality, such a major new reservoir would be operated in an integrated manner with other water rights and projects in the region.

3. Annual delivery levels were set at the project's 'firm yield', i.e. the minimum annual demand that could be supplied without shortage through a 1947-1991 period of hydrologic record. As a result the reservoir was not drawn down fully every year. Instead it carried over water from year to year, becoming nearly empty only at the end of a 20-year critical draw-down period. While this mode of operation occasionally resulted in the reservoir being full when unappropriated storable flows were available, this is a realistic portrayal of an on-stream South Platte reservoir of this size.

4. The project would store water under a new storage right that would allow for reuse to extinction of the project's yield. Therefore it was assumed that there would be no return flow contributions from the project.

Methodology

We obtained storable inflow data for the hypothetical South Platte reservoir from a previous run of Denver Water's Platte and Colorado Simulation Model (PACSM)[4]. In this run, PACSM simulated the operation of a hypothetical 5,000 cfs new junior direct flow 'export' diversion at Strontia Springs superimposed onto a metro Denver area build-out scenario. The diversions from the junior 'export' diversion were assumed to be fully consumed with no return flows. The underlying build-out scenario depicted the operation of the major metro Denver area municipal water supply systems (Denver Water, Aurora, Thornton, Englewood, etc.) at build-out demand conditions and with a variety of additional projects added. In this PACSM run, modeled flows of the South Platte River at Henderson reflected the depletions and return flows associated with the assumed metro Denver area build-out demand conditions and project additions, but with no return flows from the junior 'export' diversion.

We used the diversions available to the junior 'export' diversion to simulate operation of a hypothetical 400,000 acre-foot reservoir upstream of the Strontia Springs location. The reservoir simulation (an Excel spreadsheet model), used a daily municipal demand pattern based on historical Denver Water treated water use patterns, and an annual demand volume based on the firm yield attainable from the modeled reservoir.

---

[4] PACSM simulates operation of the Denver Water system and the systems of other related water collection systems within portions of the Platte, Colorado and Arkansas River Basins. In PACSM, rivers and water supply systems are represented as a system of "linked nodes," or measurement points, representing diversions, stream gages, reservoirs, points requiring a minimum instream flow, or any location where information is needed. The nodes – of which there are more than 450 – are linked by rivers, canals, pipelines or tunnels. The model allocates water to a diversion or reservoir based upon available flow, water rights, diversion or storage capacity, and water demand. At each node, numerous types of information are available on a daily basis throughout a 45-year hydrologic period (1947 – 1991). For example, at a reservoir, the available information includes inflow, evaporation, seepage, exchanges, reservoir releases and hydroelectric power generation (Denver Water 2002).

Flows at the South Platte at Henderson "node" were also taken from the PACSM model simulation. To these flows we added any simulated "spills" that would have occurred from the 400,000 acre-foot reservoir, which would have "added" water to the river at times when the reservoir was full, as compared to the hypothetical 5,000 cfs direct flow 'export' diversion used in the PACSM model. The adjusted modeled flows at Henderson were then compared to historical Henderson gage data. Any net depletions were assumed to translate one-for-one downstream to the Kersey gage (incorporating a 1-day travel time), while any modeled increases in flow were disregarded.

Component 2: Expanded Northern Integrated Supply Project

This component is an expanded version of the Northern Colorado Water Conservancy District's proposed Northern Integrated Supply Project (NISP), which is intended to increase M&I water supplies within the Cache La Poudre river basin without reducing agricultural supplies. Conceptually, NISP integrates two previously proposed projects: the Cache La Poudre Water & Power Project (Poudre Project) and the South Platte Water Conservation Project (Conservation Project). The Poudre Project portion of NISP would consist of a single on-stream reservoir on the mainstem Poudre or an on-stream reservoir and diversion that would feed water into an off-stream facility. The Poudre Project reservoir(s) would store unappropriated water during spring runoff months and water made available by exchange releases from the Conservation Project during the summer months.

The Conservation Project portion of NISP would include diversion facilities located near the confluence of the Poudre and South Platte Rivers that would divert unappropriated water into an off-stream reservoir for subsequent release into the lower portions of several Poudre irrigation ditches during the irrigation season. The Poudre ditches would in turn reduce their headgate diversions and the exchanged water would be diverted directly by M&I water providers or stored in the upper Poudre Reservoir(s).

A NISP participant group of 12 water provider entities has initially expressed a future need for approximately 40,000 acre-feet of new water yield and approximately 50,000 acre-feet of firming storage. For the purposes of this analysis, a much larger version of NISP was analyzed, consisting of more than 92,000 acre-feet of new yield and more than 300,000 acre-feet of storage. This version of NISP corresponded to the maximum size configuration of the project that had recently been modeled by the District. The major assumptions used in the analysis of this hypothetical project component include:

1. Combined upper Poudre storage of 220,000 acre-feet, capable of diverting from both the Mainstem and the North Fork of the Poudre.

2. Combined Poudre/South Platte confluence headgate diversion capacity of 2,100 cfs leading into a 1,600 acre-foot forebay reservoir, with a 400 cfs pipeline to an 82,000 acre-feet off-stream reservoir.

3. Diversions made under conditional water right priorities associated with the Poudre Project and the Conservation Project.

4. While diversions would produce municipal return flows, no return flows were assumed in this analysis under the assumption that, during peak flow diversion periods, return flows would be negligible.

Methodology

We relied on modeled diversion data for the upper Poudre reservoir(s) and the confluence diversion facilities as provided by Mr. Andy Pineda of NCWCD for most of this analysis. The NCWCD model simulates both the Poudre Project and Conservation Project elements of this project on a daily basis over a 1970-1994 period of hydrologic record and utilizes historical stream gage data, diversion data and Division 1 call records as constraints. For estimates of pre-1970 NISP diversions, we developed a regression analysis of total NISP monthly diversions vs. historical gaged flows of the South Platte River near Kersey. The diversion data derived from this regression analysis were further constrained by historical call data for the South Platte, as discussed below. Flow depletions caused by modeled diversions by the upper Poudre reservoir(s) were assumed to have a 1-day travel time to Kersey.

Component 3: Major Diversion Project on the South Platte Below Greeley Serving Metro Denver Area Providers

While most of the existing and projected future M&I water demand in the South Platte basin is concentrated in the metro Denver area, most of the basin's water supplies occur downstream of the metro Denver area. Consequently, some metro Denver area providers have considered developing a project that would divert water from the South Platte River below the confluence of its major tributaries. Such a project would be combined with off-stream storage and would be used to divert both unappropriated water as well as unused RRFs generated by participating metro Denver area providers (i.e. RRFs that have not been utilized locally by direct reuse, augmentation or exchange).

This third scenario component is based on such a concept. It is assumed to serve the needs of metro Denver area providers and would involve diversion of unappropriated water and RRFs not captured locally by exchange or direct reuse. The assumed diversion location of such a project would be on the South Platte just below Kersey, to take advantage of as large a drainage area as possible for capturing peak flows. For the purpose of this analysis, we assumed that all diverted water would be regulated in off-stream storage and would be fully consumed, so there would be no return flow component. Specific assumptions used in the analysis of this component include:

1. A diversion under a new junior water right below the Kersey gage with a capacity of 200 cfs with respect to unappropriated South Platte flows, plus additional capacity as needed to divert unused RRFs.

2. Off-stream storage sufficient to fully regulate and utilize diversions.

3. Diversions would be fully consumable and re-used to extinction.

4. Unused RRFs were estimated as the sum of Denver's and Aurora's total RRFs. Even though Denver and Aurora have historically reused a portion of their respective RRFs, this assumption was made in order to roughly account for unused RRFs from other metro Denver area providers.

5. Denver's RRFs were quantified by multiplying historical monthly Roberts Tunnel delivery volumes by Denver's corresponding monthly municipal consumptive use percentages. For simplicity's sake, it was assumed that all Roberts Tunnel deliveries were used directly. (In actuality, some Roberts Tunnel deliveries were exchanged to storage in Denver's South Platte reservoirs for later use).

6. Aurora's RRFs were quantified under the assumption that all of Aurora's historical raw water deliveries were reusable. Aurora's raw water deliveries for 1947-1969 were estimated on the basis of Aurora's population (interpolated from census figures) divided by a raw water use factor of five persons per AF. Aurora's raw water deliveries for 1970-1994 were obtained from Aurora's annual water supply reports. Aurora's RRFs were quantified by applying Aurora's 1999-2001 monthly municipal demand and return flow patterns to estimated annual raw water deliveries.

Methodology

This scenario component was simulated as a diversion with a maximum capacity of 200 cfs with respect to unappropriated water. Unappropriated water was quantified based on the physical availability of water at the Kersey gage and the absence of any historical

South Platte calls. Estimated unused RRFs were added to this calculated free-river diversion amount.

Component 4: Development of Multiple Reservoirs on South Platte Tributaries

In addition to major reservoir development potential on the South Platte above Denver and on the Cache La Poudre River, there exist a variety of potential on-stream and off-stream storage projects elsewhere within the South Platte basin. This scenario component represents a collection of relatively small new reservoirs or reservoir expansion projects that could cumulatively reduce peak flows at and below Kersey in a significant manner. The example projects included in this component include:

- An expanded Gross Reservoir storing water on South Boulder Creek
- An enlargement of Button Rock Reservoir storing water on North St. Vrain Creek
- Reuter-Hess Reservoir storing water from Cherry Creek (currently proposed by the Parker Water & Sanitation District)
- An enlargement of Standley Lake storing water from Clear Creek
- Dispersed gravel pit storage along the South Platte and the lower portions of the major South Platte tributaries

It is assumed that all of these projects would divert unappropriated peak flows into storage for municipal use. As with other scenario components, return flows from water supplies developed under this scenario component were ignored or assumed to be negligible. Assumptions used in the analysis of this component include:

1. These projects would capture only unappropriated native waters during peak flow conditions.

2. All of these projects would be located upstream of the Kersey gage.

Methodology

Through a series of statistical analyses, we estimated the total impact of these various projects as a function of historical flows at Kersey.

Gross Reservoir Enlargement: An analysis of historical daily storage rates of South Boulder Creek water into Gross Reservoir were compared with daily flows at Kersey. The median value for Gross's rate of storage of native water was 3.0% of historical Kersey gage flows.

Button Rock and Standley Enlargements: Existing daily storage diversion data for Button Rock and Standley are much more complex due to numerous exchanges and changes of water rights. Sorting through these data was beyond the scope of the study. We therefore assumed the same percentage of Kersey gage flows for the rates of storage for Button Rock enlargement and Standley enlargement as was assumed for Gross enlargement. This is reasonable in the case of Button Rock enlargement because of the similarity of the South Boulder Creek and North St. Vrain basins, both in terms of virgin flow hydrology tributary to both reservoirs and local downstream senior water rights.

In the case of a Standley enlargement, while Clear Creek is a much larger stream in terms of virgin flow, Standley's rate of fill would be limited by the capacities of the Croke Canal and Church Ditch and by proportionately greater demands from local downstream senior rights. This can be seen in the Croke Canal's historical diversions, which have rarely exceeded 200 cfs for more than seven days. We therefore assumed the same percentage (3%) of Kersey gage flows for the rate of storage in a Standley enlargement.

Thus the typical combined rate of storage of these three mountain tributary storage projects can be roughly estimated as 9% of the historical Kersey gage flow when there is no call.

Reuter Hess and Dispersed Gravel Pit Storage: Reuter Hess Reservoir and gravel pit storage would comprise off-stream storage with typically limited rates of fill. As a rough estimate, we increased the 9% figure to 11% to account for the combined rate of storage into gravel pits and Reuter Hess reservoir.

The total impact of these projects was thus estimated to be 11% of the total Kersey gage flow during identified peak flow periods, subject to legal availability as evidenced by historical call data.

Project 5: Reuse to Extinction of All RRFs from the Metro Denver Area.

This final component simulated the effects of complete re-use of all unused RRFs generated by metro Denver area providers that historically occurred during the 1947-1994 hydrologic period. The historical fate of these unused RRFs was typically that they became part of the allocable flow of the river below Kersey[5]. During the irrigation season, most of these unused RRFs were diverted by downstream irrigation rights and thus did not contribute significantly to peak flows. During non-irrigation months, most of these unused RRFs were diverted by the major downstream agricultural storage reservoirs: Empire, Jackson, Riverside, Prewitt, North Sterling and Julesburg. These reservoirs normally begin filling in November and finish filling in April or early May. Absent the availability of historical unused RRFs during the non-irrigation season, these reservoirs would fill longer into the spring runoff period. This in turn may result in some reduction in peak flows.

[5] Some providers have historically leased their unused RRFs to specific downstream users. However, this practice historically accounted for a relatively small amount of the total unused RRFS.

Methodology

For unused RRF estimates, we used the same data that was developed for Component 3 above. We then summed the total RRFs for November through March of each year and assumed that all of this water would be reused to extinction, thereby reducing the combined historical storage levels of the six agricultural reservoirs listed above. Starting each April 1, we then estimated how many additional days of diversions by these reservoirs would be required to make up for the RRFs that were no longer available. A spreadsheet model simulated the reservoirs' filling by diverting available water (free-river) until the cumulative additional diversion equaled the lost RRF volume.

Incorporation of South Platte Call Data and Flow Constraints

We applied a constraint represented by historical South Platte calls as recorded by the State Engineer to the initially calculated flow reductions from the five scenario components. During any identified peak flow event when there was a historical call, we assumed that the scenario components could not divert and there would be no effect on peak flows. Because we are assuming all of the scenario components would divert under relatively junior water rights, they would not impact peak flow at Kersey when there was a historical call.

As a second constraint, we limited the combined diversions by scenario components to the estimated amount of continuous historical flow in the South Platte River between Kersey and Julesburg. While the first constraint eliminates any peak reductions during a call, we needed to further limit the calculated flow reductions so as to avoid drying up the river at any location during times of historical free-river conditions, which would have created a call situation. Using point-flow studies previously conducted by NCWCD and USBR, we estimated the minimum flow between Kersey and Julesburg during each identified peak flow event. These minimum 'point flows' provided an upper bound on the amount of additional water that could be diverted by the scenario components, using the logic that if any section of the river between Kersey and Julesburg went dry, a call would be initiated.

Analysis of Downstream Attenuation Factors

As an additional constraint, we further limited the calculated flow reductions at Overton to the minimum flow in the river between Julesburg and Overton by conducting a point flow analysis between those locations. We used daily gage data and diversion data to estimate the minimum flows for the relevant peak flow events at 5 locations between Julesburg and Overton:

- South Platte below Korty diversion
- South Platte at North Platte
- Platte River below Tri-County diversion
- Platte River at Brady
- Platte River near Cozad

The South Platte below Korty diversion and the Platte River below Tri-County diversion are the major instream flow 'bottlenecks' between Julesburg and Overton because of the relatively large volumes of diversions that occur at these locations.

While the historical daily data for these five locations are relatively complete, there were some locations and time periods with missing data that we addressed in the following manner.

South Platte Below Korty Diversion

For 1947 through April 1970, we estimated flows at this location as being equivalent to the gaged flow at the South Platte River at Paxton. For May 1970 through 1994 we estimated flows by subtracting South Platte Supply Canal diversions from South Platte River (Korty Canal) from the South Platte River flow at Roscoe, using Roscoe gage data for May 1970 through September 1982 and estimated Roscoe flows (developed by correlation analysis with Julesburg flows) for October 1982 through 1994.

Platte River below Tri-County Diversion

For 1958 through 1994, we estimated flows at this location as being equivalent to the gaged flow at the Platte River below Tri-County Diversion Dam. For periods of missing gage data during peak flow events in these years and for the years 1947 through 1957, we estimated flows by subtracting Tri-County Canal diversions from gaged flows at the confluence of the North and South Platte Rivers near North Platte, or from estimated flows developed for this location by correlation analysis with the sum of the South Platte, North Platte and Sutherland power return flows at North Platte.

South Platte / Platte River Diversion Offsets

The net impact of Colorado's future flow reductions within the constraints of river flows and diversions downstream of Julesburg were computed as follows. We start with the assumption that that the calculated peak flow reductions at Julesburg would have a limited impact on peak flows at Overton due to the intervening minimum flows at these five locations, and that any remaining calculated flow reductions at Julesburg would have resulted in reductions to historical diversions from the South Platte River by the Sutherland and Tri-County projects. These reductions to diversions would not necessarily cause an immediate impact to peak flows at Overton. However, they would generally result in increased McConaughy releases and/or additional diversions from existing North Platte river flows to compensate for the reduced supply from the South Platte River. If additional North Platte flows were diverted to offset the reduction in South Platte flows, there would be an immediate impact at Overton. If additional releases are made from McConaughy, the impacts would consist of reduced flows during periods when McConaughy is capturing additional water to fill the "hole" from those additional releases.

A complicating factor in this analysis is that because of the physical structure of the river and diversion canal system in Nebraska, we cannot simply assume that the minimum river point flow is representative of the maximum flow reduction at Overton. In particular, we need to consider the sections above and below the North Platte / South Platte confluence independently, as described below.

To offset reduced diversions from the Korty diversion canal, we assume that additional water from the North Platte would be delivered via the Sutherland Canal. If this water comes from additional releases from storage, then there is no immediate net impact to river flows below the confluence. If, however, waters that are already in the North Platte river channel are diverted, then although the Sutherland system is kept whole, there is a net depletion to the flows at the confluence. Computing the impacts at Tri-County, then, requires accounting for reduced river flows past Korty PLUS any reductions to North Platte flows taken to offset the Korty diversion reductions.

To incorporate the impacts of offsetting diversions, we conducted an additional point flow study between Lake McConaughy and the South Platte / North Platte confluence. We assumed that any reductions in Korty diversions would be offset first by additional diversions from existing North Platte flows first, then from additional McConaughy releases. The North Platte gages at Keystone, Sutherland, and at the town of North Platte were used for this analysis. A mass-balance was then performed to estimate total depletions at the confluence, including any depletions of North Platte flows. Next, we considered the Tri-County diversion, again depleting the river to the maximum extent possible before requiring offsets by additional McConaughy releases. Note that as of the time of this report, we have not taken into consideration various potential limiting factors including diversion limits, canal travel times, depletions, and losses, and whether or not offset water would actually be available for release from McConaughy.

While the results presented herein provide us with an estimate of the direct impacts on peak flows at Overton, they do not yet include an analysis of whether or not there is sufficient water available in McConaughy to offset these reductions, and how the additional releases from McConaughy and the resulting fill periods will impact flows at other times of the year. We are providing estimates of these monthly releases to Interior, who will be performing that analysis using the Central Platte Ops Study Model. Results of that analysis will be incorporated into this report when they become available.

An example of our overall analytical process as implemented in our spreadsheet model is shown in Figure 2, using data from the 1-day analysis. Note that the example shown only estimates impacts at Overton due to projects and constraints above Julesburg. A similar analysis for the Julesburg to Overton reaches further constrains the results shown here.

Peak Flow Analysis: Peak 1-day event (All values CFS)

Gage Data:								
Platte River Near Overton, NE	6/23/1947	13900		6/23/1948	4480		6/24/1949	14700
Lag Equation = 13.193 - 0.0002 Q (Days)	Lag (days)	10			12			10
South Platte at Kersey: flow at lagged date as specified by regression	6/13/1947	6770		6/11/1948	6770		6/14/1949	17200
Project Impacts:								
Flow reductions due to utilization of RRFs by Aurora (DIRECT, Not secondary due to Reservoir fills)	6/12/1947	1		6/10/1948	1		6/13/1949	1
Flow reductions due to utilization of RRFs by Denver (DIRECT, Not secondary due to Reservoir fills)	6/12/1947	0		6/10/1948	0		6/13/1949	0
Flow reductions due to utilization of RRFs by Aurora and Denver (secondary due to Reservoir fills)	6/13/1947	0		6/11/1948	0		6/14/1949	0
Flow reductions due to Denver Metro Area Pump-Back at Kersey	6/13/1947	200		6/11/1948	200		6/14/1949	200
Flow reductions due to Tributary Reservoir Development	6/12/1947	440		6/10/1948	194		6/13/1949	1254
Flow reductions due to Development Upstream of Denver	6/12/1947	1297		6/10/1948	1186		6/13/1949	3132
Flow reductions due to Poudre Project Development	6/13/1947	621		6/11/1948	167		6/14/1949	887
TOTAL POTENTIAL REDUCTION DUE TO NEW USE	**6/13/1947**	**2559**		**6/11/1948**	**1748**		**6/14/1949**	**5473**
Constraints:								
Minimum South Platte Flows based on Point Flow modeling analysis - South Platte River - Kersey to Julesburg	6/13/1947	1410		6/11/1948	53		6/14/1949	6141
Flows available for further depletion	6/13/1947	1410		6/11/1948	53		6/14/1949	6141
TOTAL REDUCTION DUE TO NEW USE CONSTRAINTED BY MINIMUM AVAILABLE FLOWS	6/13/1947	1410		6/11/1948	53		6/14/1949	5473
Call ON (1) or OFF (0)?	6/13/1947	0		6/11/1948	0		6/14/1949	0
TOTAL REDUCTION DUE TO NEW USE CONSTRAINTED BY MINIMUM AVAILABLE FLOWS AND SP CALLS	6/13/1947	1410		6/11/1948	53		6/14/1949	5473
Minimum South Platte/Platte Flows based on Point Flow modeling analysis - Julesburg to Overton	6/23/1947	451		6/23/1948	9		6/24/1949	13400
TOTAL REDUCTION DUE TO NEW USE CONSTRAINTED BY MINIMUM AVAILABLE FLOWS AND SP CALLS AND PLATTE PT FLOW	6/13/1947	451		6/11/1948	9		6/14/1949	5473
Result at Overton:								
ADJUSTED PEAK FLOWS AT OVERTON	6/23/1947	13449		6/23/1948	4471		6/24/1949	9227

Figure 2. Example of analysis process for 1-Day peak events.

Results and Discussion

Worst case impacts to 1-day, 3-day, and 30-day peak flow events at Overton are presented in tabular form in the attached Appendix, and are shown graphically in Figures 3-5, respectively. Average, median, minimum, and maximum reductions in peak flows, both as absolute flow values and percentages, are shown in Table 2. The distribution of the events by month (based on starting date of the event) is shown in Figure 6. Actual annual reductions in flows are shown in Figure 7. Frequency distributions of worst case impacts to 1-day, 3-day and 30-day peak flow events are shown in Figures 8-10.

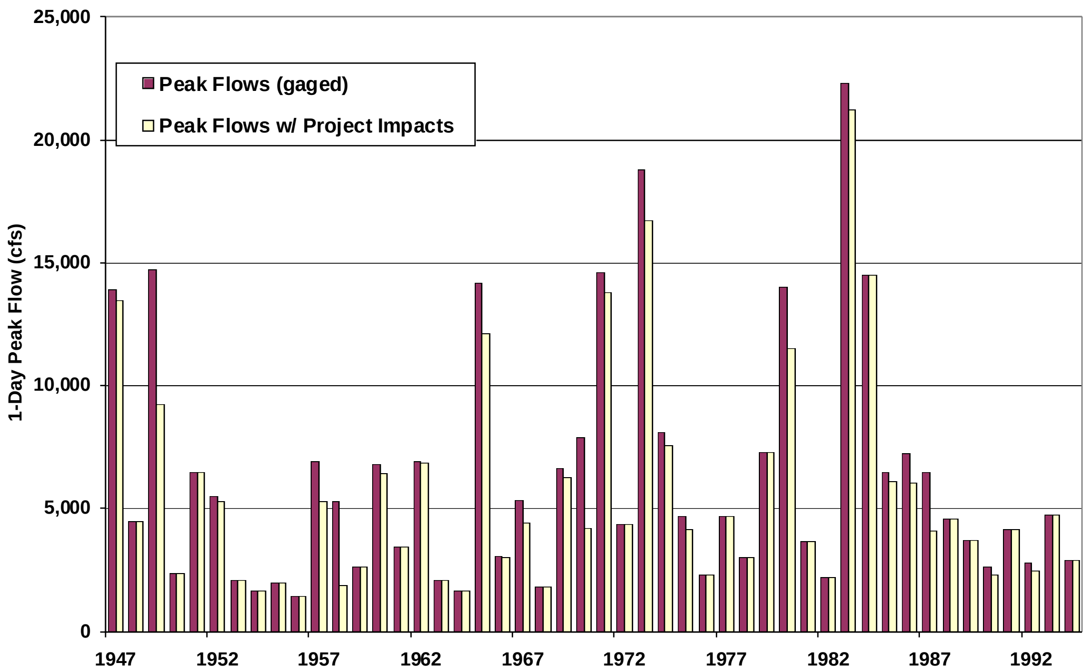

Figure 3. Potential impacts of future Colorado water development on 1-Day peak flows at Overton, NE.

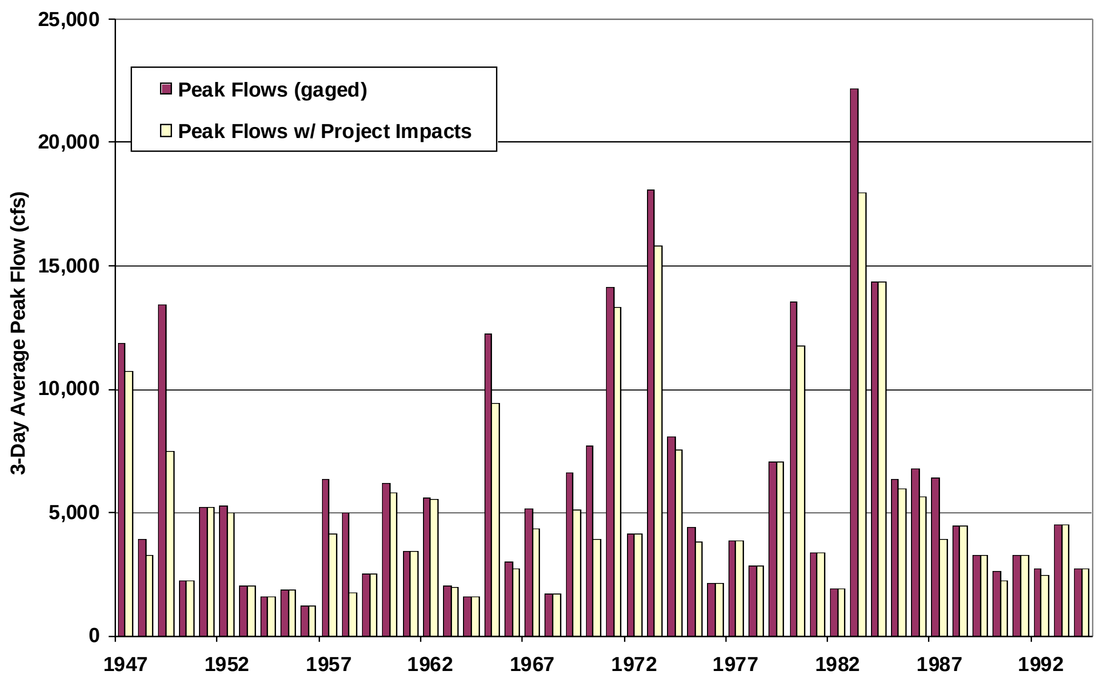

Figure 4. Potential impacts of future Colorado water development on 3-Day peak flows at Overton, NE.

As expected, the most significant reductions to peak flows are likely to occur in years with relatively high flows during free river conditions. While calls on the South Platte did reduce the number of years during which water was available, it is interesting to note that in several low-flow years the peak flow occurred before calls were placed on the river.

Another interesting trend is the large number of peak events that happen early in the year. Peak flow events in February and March account for about 1/3 of all events across all three categories (1, 3, and 30-day), although the peaks during February and March are typically lower than the peaks in April, May and June. Peak flow reductions during these early months are rarely constrained by historical calls.

The analysis demonstrated that attenuation effects from intervening stream flow conditions between Julesburg and Overton played a major role in limiting the impacts of the reasonable worst case scenario on peak flows at Overton. Furthermore, there would be significant impacts to North Platte River operations, primarily due to a significant increase in McConaughy releases to offset reductions in divertable water at the Korty and Tri-County diversion headgates.

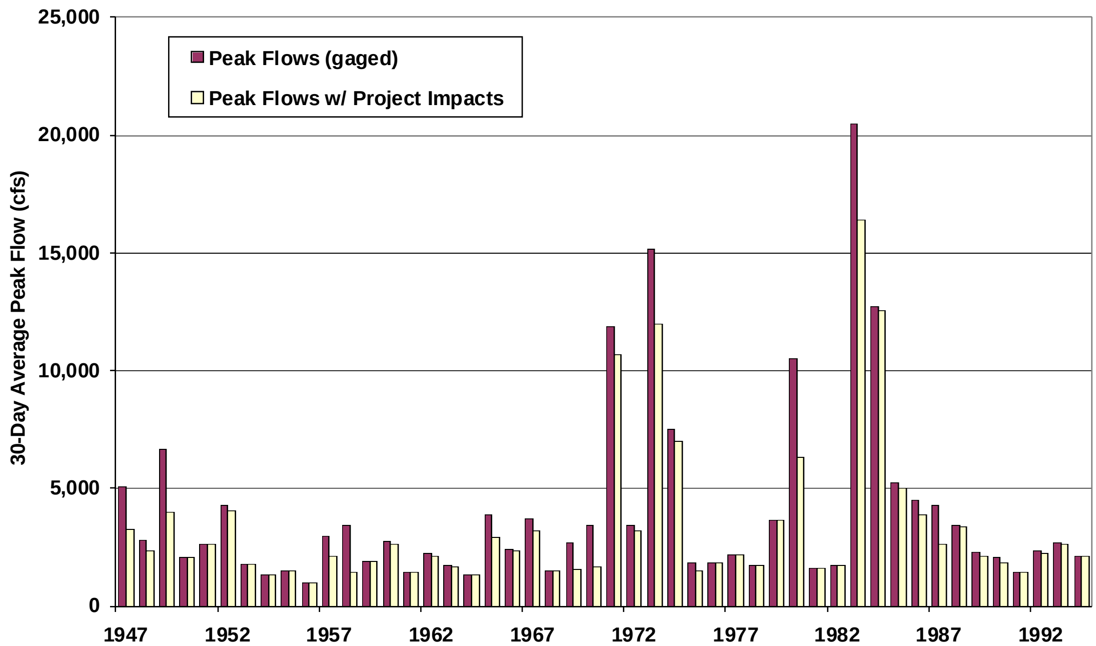

Figure 5. Potential impacts of future Colorado water development on 30-Day peak flows at Overton, NE.

Table 2. Summary statistics of impacts to peak flows

Reduction of Peak Flows (pct)	1 Day Peak	3 Day Average Peak	30 Day Average Peak
Minimum	0.0%	0.0%	0.0%
Average	7.6%	9.5%	11.3%
Median	0.1%	1.1%	4.4%
Maximum	63.9%	64.7%	58.4%
Reduction of Peak Flows (cfs)			
Minimum	0	0	0
Average	644	785	618
Median	5	38	136
Maximum	5473	5919	4210

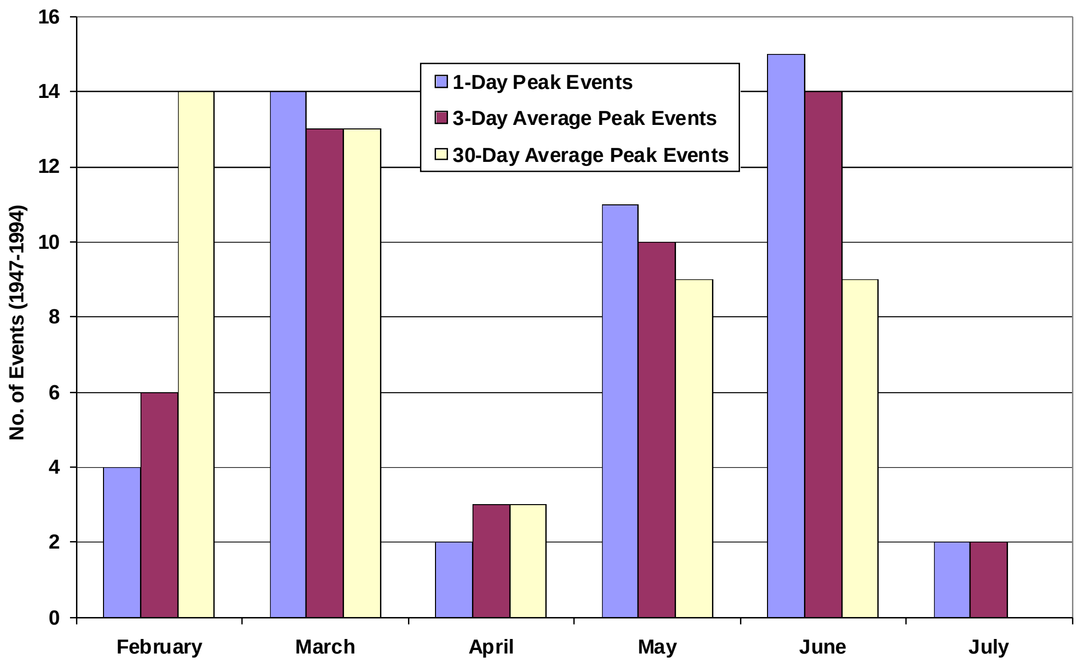

Figure 6. Frequency of peak flow events (1947-1994) by month.

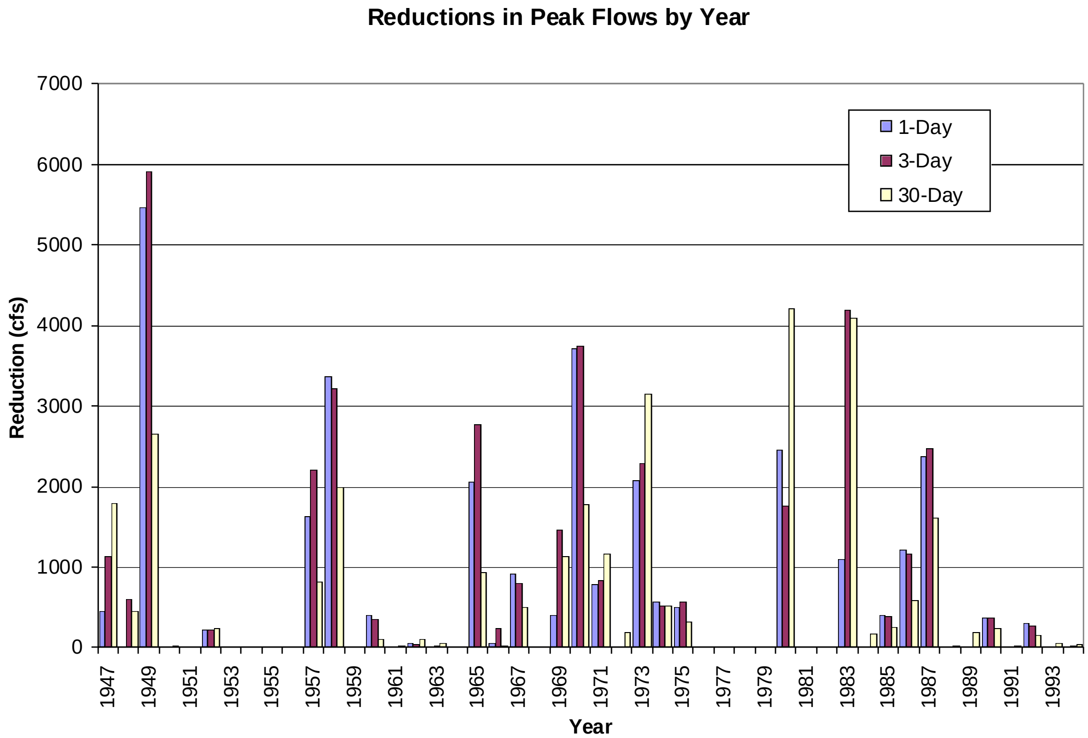

Figure 7. Reductions in peak flows by year.

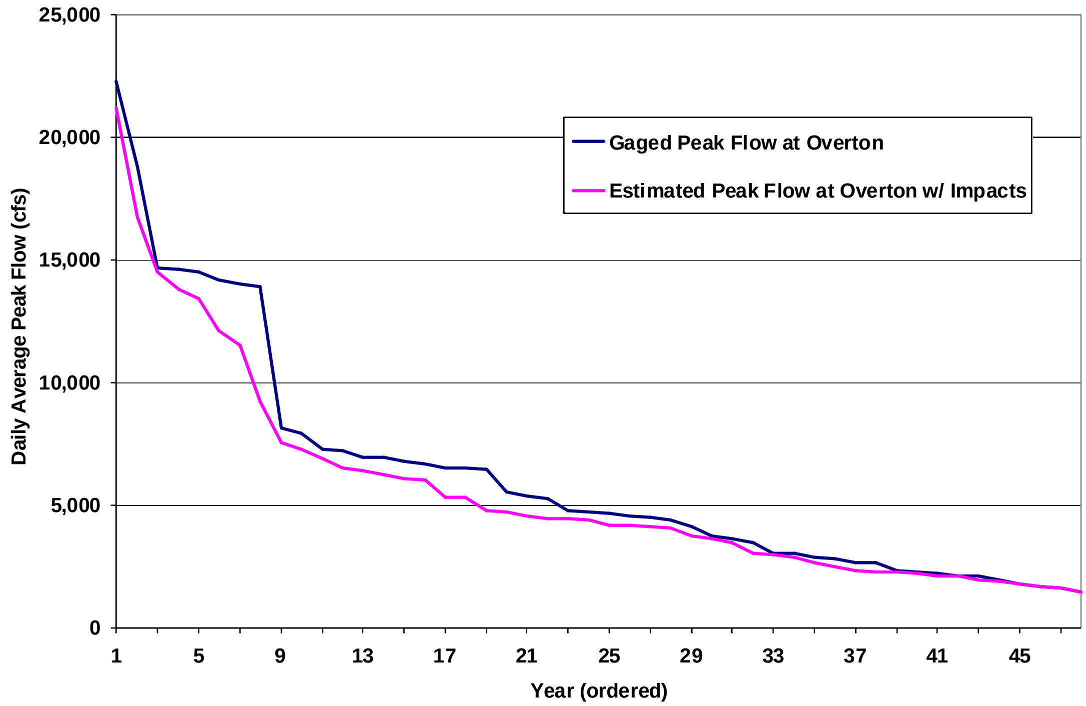

Figure 8: Peak Flow Exceedence Curves - Annual 1-Day Peak, 1947-1994

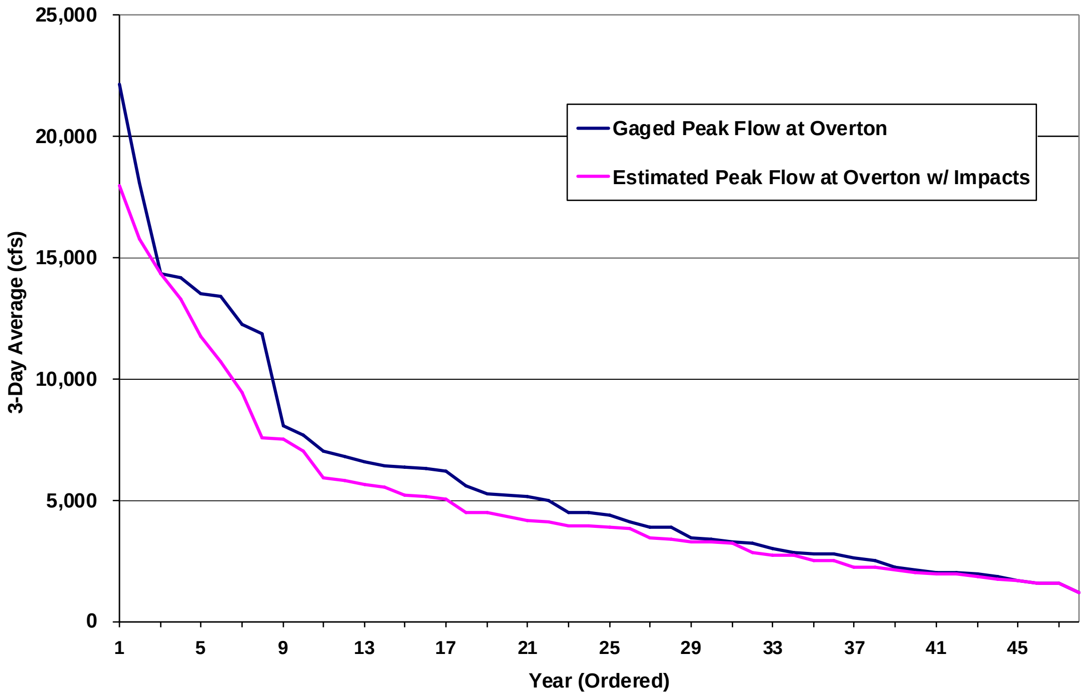

Figure 9: Peak Flow Exceedence Curves - Annual 3-Day Peak, 1947-1994

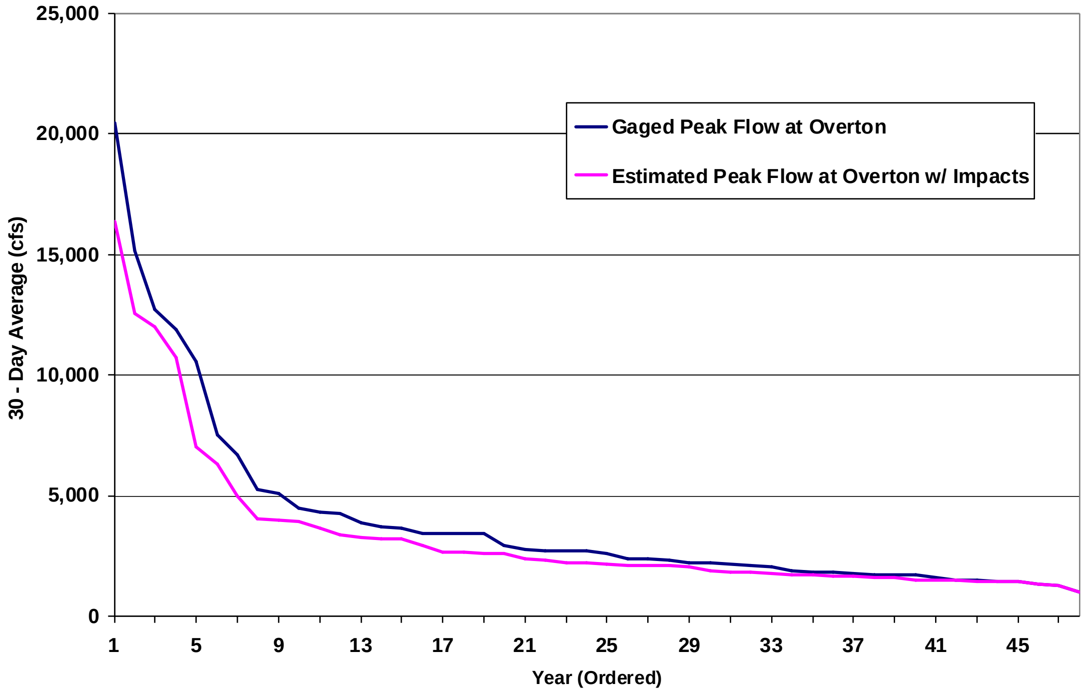

Figure 10: Peak Flow Exceedence Curves - Annual 30-Day Peak, 1947-1994

The additional analysis of daily data for the entire period of record resulted in the flow frequency curves shown in figures 11 and 12 (with data in Appendix B). That graphic also shows the percent reduction in flow at each integer exceedence level (i.e., 99%, 98%, 97%, etc.).

One of the most significant assumptions made in performing the analyses presented above is that any reductions in diversions between Julesburg and Overton (in particular, at Korty and Tri-County), would be offset by additional water from the North Platte. This would ensure that return flow patterns, which are an important component of the flow regime in the Platte, remain essentially unchanged. However, to achieve this offset would require large amounts of water from the North Platte. Figure 13 shows the annual additional releases from McConaughy that would be required to offset the reduced water available from the South Platte. We have provided these data on a monthly basis (see Appendix C) to Interior for input into the Central Platte Ops Study Model.

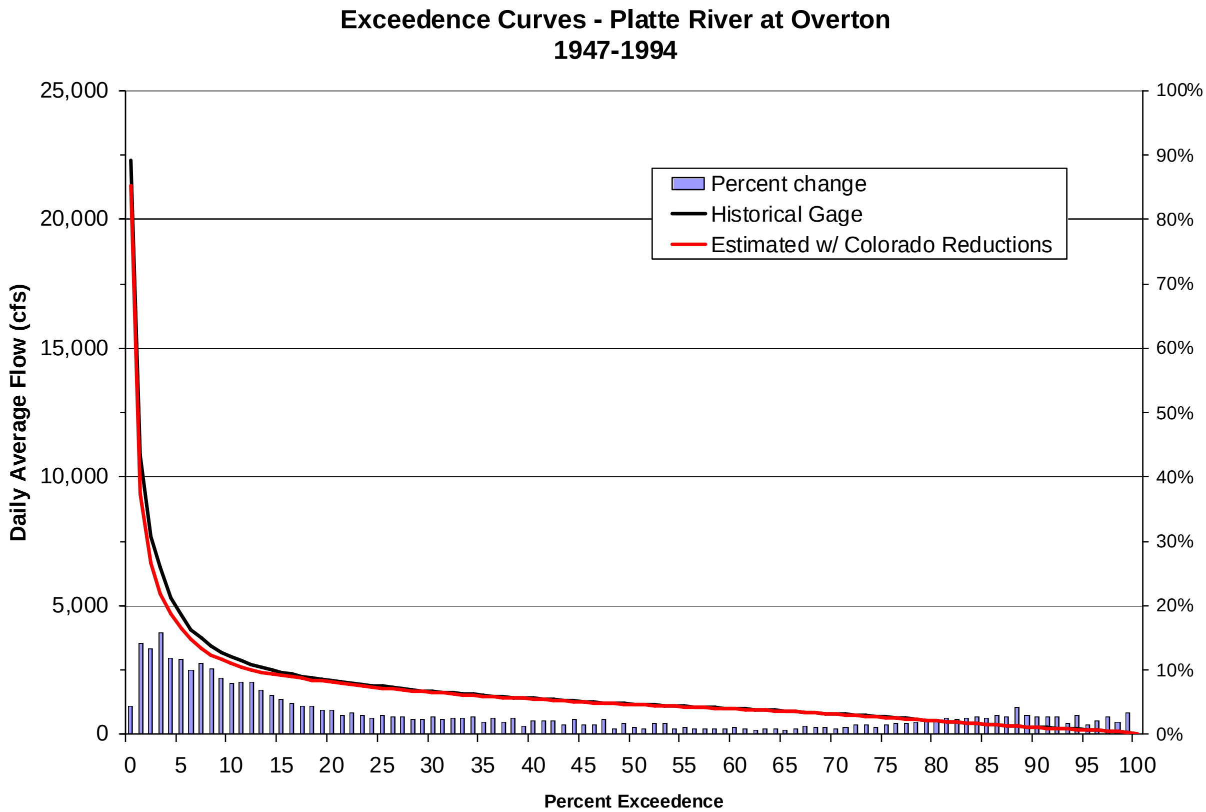

Figure 11. Exceedence curve for flows based on 1947-1994 daily data, before and after impacts of future Colorado depletions. Bars show percent reduction in flow for each percentage threshold.

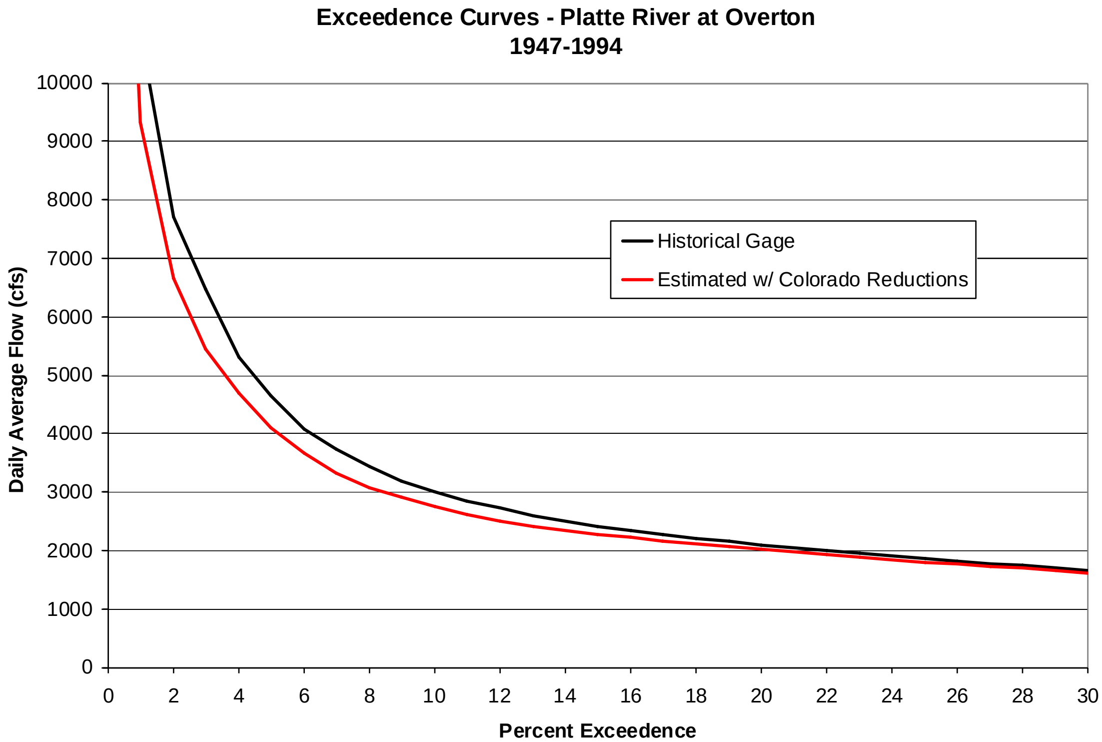

Figure 12. Detail of Figure 11: 0% - 30% Exceedence Flows.

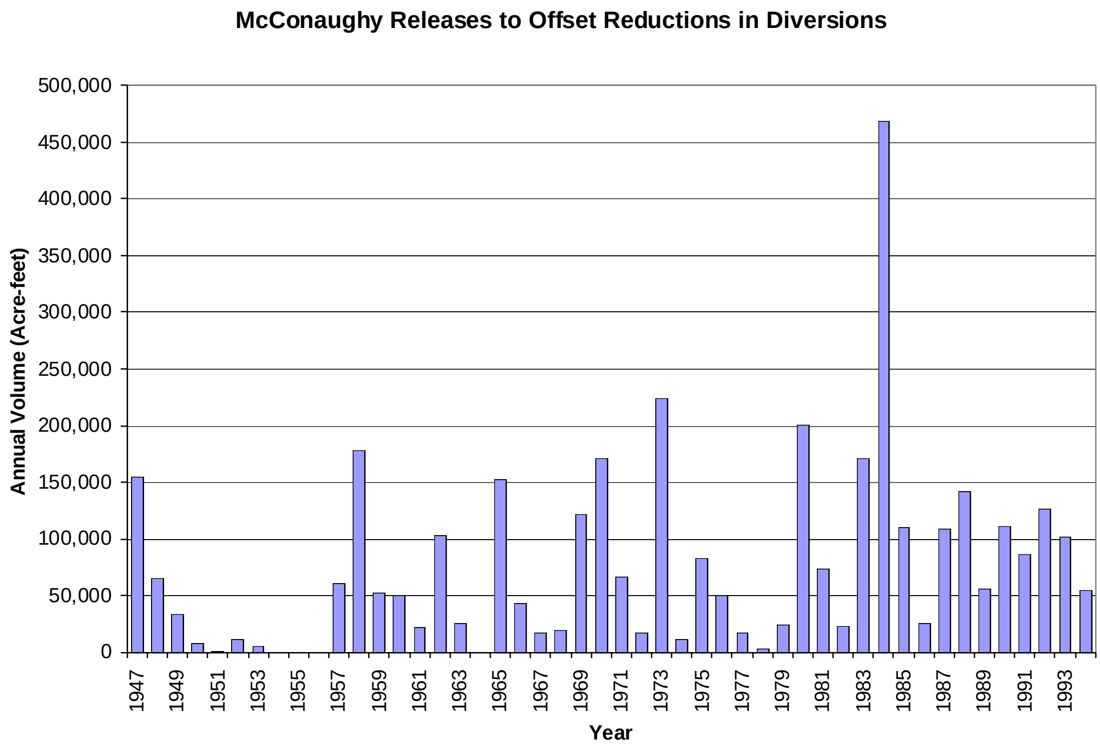

Figure 13. Annual volume of additional McConaughy releases required to offset reduced diversions due to future Colorado flow reductions.

Appendix A: Yearly Results of Peak Flow Analysis

The following tables provide a year-by-year summary of the peak flow analyses for each of the 1-day, 3-day, and 30-day peak flow periods. For the 3-day and 30-day events, the date shown represents the first day of the period. These results are summarized in Table 1 of the report.

1 Day Average

Year	Date	Peak Flows (gaged, cfs)	Peak Flows w/ Project Impacts (cfs)	Reduction in Peak Flow (cfs)	%Reduction
1947	6/23	13900	13449	451	3.2%
1948	6/23	4480	4471	9	0.2%
1949	6/24	14700	9227	5473	37.2%
1950	3/18	2340	2340	0	0.0%
1951	5/18	6510	6510	0	0.0%
1952	3/27	5530	5312	218	3.9%
1953	3/15	2090	2090	0	0.0%
1954	3/10	1640	1640	0	0.0%
1955	3/10	1960	1960	0	0.0%
1956	6/21	1450	1450	0	0.0%
1957	5/26	6940	5308	1632	23.5%
1958	5/27	5270	1901	3369	63.9%
1959	3/1	2650	2650	0	0.0%
1960	3/24	6810	6409	401	5.9%
1961	6/19	3470	3470	0	0.0%
1962	6/9	6930	6876	54	0.8%
1963	2/22	2100	2100	0	0.0%
1964	4/7	1670	1670	0	0.0%
1965	6/26	14200	12140	2060	14.5%
1966	3/21	3050	2996	54	1.8%
1967	7/8	5360	4442	918	17.1%
1968	2/22	1800	1800	0	0.0%
1969	6/30	6670	6270	400	6.0%
1970	6/26	7910	4200	3710	46.9%
1971	6/12	14600	13816	784	5.4%
1972	5/15	4380	4380	0	0.0%
1973	5/16	18800	16729	2071	11.0%
1974	3/20	8130	7561	569	7.0%
1975	6/22	4670	4170	500	10.7%
1976	4/11	2280	2280	0	0.0%
1977	5/22	4710	4710	0	0.0%
1978	3/15	3020	3020	0	0.0%
1979	6/27	7280	7280	0	0.0%
1980	5/25	14000	11540	2460	17.6%
1981	7/29	3640	3640	0	0.0%
1982	3/9	2230	2230	0	0.0%
1983	6/22	22300	21200	1100	4.9%
1984	5/7	14500	14500	0	0.0%
1985	2/23	6500	6103	397	6.1%
1986	6/18	7240	6029	1211	16.7%
1987	5/31	6470	4090	2380	36.8%
1988	2/25	4560	4560	0	0.0%
1989	6/27	3740	3740	0	0.0%
1990	5/2	2650	2281	369	13.9%
1991	5/24	4140	4140	0	0.0%
1992	3/15	2800	2500	300	10.7%
1993	3/10	4770	4770	0	0.0%
1994	3/5	2880	2880	0	0.0%

3 Day Average

Year	Date (first day of period)	Peak Flows (gaged, cfs)	Peak Flows w/ Project Impacts (cfs)	Reduction in Peak Flow (cfs)	%Reduction
1947	6/22	11860	10736	1124	9.5%
1948	3/17	3913	3303	611	15.6%
1949	6/24	13433	7515	5919	44.1%
1950	4/5	2250	2236	14	0.6%
1951	5/17	5200	5200	0	0.0%
1952	3/26	5247	5029	218	4.2%
1953	3/14	2043	2042	1	0.1%
1954	3/9	1603	1603	0	0.0%
1955	3/9	1857	1857	0	0.0%
1956	6/20	1200	1200	0	0.0%
1957	5/24	6363	4151	2212	34.8%
1958	5/26	4980	1756	3224	64.7%
1959	2/27	2537	2537	0	0.0%
1960	3/23	6183	5821	362	5.9%
1961	6/18	3427	3427	0	0.0%
1962	6/8	5613	5565	49	0.9%
1963	2/21	2013	1987	26	1.3%
1964	4/28	1603	1603	0	0.0%
1965	6/26	12230	9458	2772	22.7%
1966	3/2	2983	2750	233	7.8%
1967	7/11	5160	4355	805	15.6%
1968	2/22	1697	1696	1	0.1%
1969	6/30	6600	5129	1471	22.3%
1970	6/25	7683	3935	3749	48.8%
1971	6/12	14167	13329	838	5.9%
1972	5/14	4130	4126	4	0.1%
1973	5/15	18100	15801	2299	12.7%
1974	3/19	8077	7554	522	6.5%
1975	6/21	4397	3821	576	13.1%
1976	2/1	2150	2150	0	0.0%
1977	5/22	3877	3877	0	0.0%
1978	3/15	2833	2833	0	0.0%
1979	6/26	7037	7037	0	0.0%
1980	5/25	13533	11780	1753	13.0%
1981	7/28	3403	3403	0	0.0%
1982	3/9	1950	1950	0	0.0%
1983	6/28	22167	17970	4197	18.9%
1984	5/5	14367	14367	0	0.0%
1985	2/23	6337	5952	384	6.1%
1986	6/17	6813	5648	1166	17.1%
1987	5/30	6397	3930	2467	38.6%
1988	2/23	4490	4490	0	0.0%
1989	6/26	3257	3257	0	0.0%
1990	4/30	2620	2247	373	14.2%
1991	5/23	3267	3267	0	0.0%
1992	3/14	2763	2486	277	10.0%
1993	3/9	4503	4503	0	0.0%
1994	3/4	2763	2748	16	0.6%

30 Day Average

Year	Date (first day of period)	Peak Flows (gaged, cfs)	Peak Flows w/ Project Impacts (cfs)	Reduction in Peak Flow (cfs)	%Reduction
1947	6/22	5082	3282	1800	35.4%
1948	2/24	2788	2335	453	16.3%
1949	6/7	6678	4016	2662	39.9%
1950	3/17	2086	2069	17	0.8%
1951	5/17	2622	2622	0	0.0%
1952	2/29	4295	4060	235	5.5%
1953	2/22	1793	1790	3	0.2%
1954	2/1	1335	1335	0	0.0%
1955	2/14	1493	1491	2	0.2%
1956	3/15	1012	1012	0	0.0%
1957	5/13	2961	2151	810	27.4%
1958	5/14	3419	1423	1996	58.4%
1959	3/13	1889	1880	9	0.5%
1960	3/16	2733	2619	113	4.1%
1961	5/28	1463	1437	26	1.8%
1962	3/4	2233	2128	105	4.7%
1963	2/1	1717	1666	50	2.9%
1964	3/16	1311	1311	0	0.0%
1965	6/12	3875	2945	930	24.0%
1966	3/10	2411	2380	31	1.3%
1967	6/15	3718	3215	503	13.5%
1968	2/22	1510	1508	2	0.1%
1969	6/11	2723	1590	1133	41.6%
1970	6/9	3443	1671	1772	51.5%
1971	5/23	11877	10708	1169	9.8%
1972	3/6	3417	3227	190	5.6%
1973	5/14	15137	11993	3144	20.8%
1974	3/19	7533	7021	512	6.8%
1975	6/3	1847	1519	328	17.8%
1976	2/1	1828	1828	0	0.0%
1977	3/30	2210	2210	0	0.0%
1978	3/13	1727	1727	0	0.0%
1979	6/11	3673	3673	0	0.0%
1980	5/10	10538	6328	4210	40.0%
1981	2/13	1597	1597	0	0.0%
1982	2/17	1711	1711	0	0.0%
1983	6/8	20477	16386	4091	20.0%
1984	4/29	12723	12557	166	1.3%
1985	2/18	5270	5009	261	5.0%
1986	4/12	4507	3919	588	13.0%
1987	5/22	4257	2649	1607	37.8%
1988	2/13	3413	3387	26	0.8%
1989	2/22	2324	2136	189	8.1%
1990	4/8	2062	1818	244	11.8%
1991	5/23	1451	1435	16	1.1%
1992	3/4	2380	2221	159	6.7%
1993	3/2	2708	2652	55	2.0%
1994	2/15	2153	2109	44	2.0%

Appendix B: Exceedence Values – Period of Record (1947-1994)

Flow Exceedence Values (cfs)

Pct Exceedence	Historical	W/ Colorado Impacts	pct change
0%	22300	21300	4.5%
1%	10869	9337	14.1%
2%	7698	6671	13.3%
3%	6470	5450	15.8%
4%	5318	4689	11.8%
5%	4639	4100	11.6%
6%	4081	3674	10.0%
7%	3740	3323	11.1%
8%	3430	3080	10.2%
9%	3200	2920	8.7%
10%	3000	2760	8.0%
11%	2850	2615	8.3%
12%	2720	2500	8.1%
13%	2600	2422	6.8%
14%	2500	2350	6.0%
15%	2410	2281	5.4%
16%	2340	2226	4.9%
17%	2270	2170	4.4%
18%	2210	2114	4.3%
19%	2150	2070	3.7%
20%	2100	2020	3.8%
21%	2040	1978	3.0%
22%	2000	1930	3.5%
23%	1950	1890	3.1%
24%	1900	1850	2.6%
25%	1860	1804	3.0%
26%	1820	1770	2.7%
27%	1780	1730	2.8%
28%	1740	1700	2.3%
29%	1700	1660	2.4%
30%	1670	1623	2.8%
31%	1640	1600	2.4%
32%	1600	1560	2.5%
33%	1580	1538	2.7%
34%	1550	1507	2.8%
35%	1510	1480	2.0%
36%	1490	1453	2.5%
37%	1460	1430	2.1%
38%	1440	1404	2.5%
39%	1410	1390	1.4%
40%	1390	1360	2.2%
41%	1370	1340	2.2%
42%	1340	1310	2.2%
43%	1310	1290	1.5%
44%	1300	1270	2.3%
45%	1270	1250	1.6%
46%	1250	1230	1.6%
47%	1230	1200	2.4%
48%	1200	1190	0.8%
49%	1190	1170	1.7%
50%	1170	1157	1.1%

Pct Exceedence	Historical	W/ Colorado Impacts	pct change
51%	1150	1140	0.9%
52%	1140	1120	1.8%
53%	1120	1100	1.8%
54%	1100	1090	0.9%
55%	1090	1077	1.2%
56%	1070	1060	0.9%
57%	1050	1040	1.0%
58%	1030	1020	1.0%
59%	1010	1000	1.0%
60%	997	985	1.2%
61%	978	969	0.9%
62%	960	953	0.7%
63%	944	936	0.9%
64%	924	915	1.0%
65%	904	898	0.7%
66%	888	880	0.9%
67%	870	859	1.3%
68%	847	838	1.1%
69%	822	813	1.1%
70%	800	792	1.0%
71%	776	768	1.0%
72%	752	741	1.5%
73%	725	714	1.6%
74%	699	691	1.1%
75%	675	664	1.6%
76%	647	636	1.7%
77%	619	608	1.8%
78%	596	584	2.0%
79%	565	552	2.3%
80%	536	524	2.2%
81%	508	495	2.6%
82%	478	467	2.3%
83%	450	438	2.7%
84%	426	414	2.8%
85%	400	390	2.5%
86%	375	364	2.9%
87%	350	340	2.9%
88%	326	312	4.3%
89%	301	292	2.9%
90%	280	272	2.9%
91%	259	252	2.7%
92%	241	234	2.7%
93%	222	218	1.8%
94%	206	200	2.9%
95%	186	183	1.6%
96%	166	163	2.1%
97%	149	145	2.7%
98%	128	125	2.1%
99%	95	92	3.5%
100%	18	18	0.0%

Appendix C: Annual Releases from McConaughy

The following table provides a month-by-month total of the volume of water that would need to be released from Lake McConaughy to offset the reductions in diversions by Korty and Tri-County due to future Colorado depletions of flows. Some important assumptions to note in the development of these values include:

1. We have assumed that there are no transit losses or other depletions from the Keystone Diversion, through Sutherland Canal, to the return point in the South Platte. We have also assumed a travel time of zero days.

2. We have made no considerations as to whether or not there is physical capacity in any part of the system to deliver the requisite amount of water.

3. We have not considered whether or not there is water in storage in Lake McConaughy or elsewhere to make the required additional releases.

4. We have assumed that any available water already in the North Platte below McConaughy, subject to minimum flows between McConaughy and the confluence, will be diverted first, with Lake Mac releases making up any additional deficit.

These results are summarized annually in Figure 13 of the report.

McConaughy Releases to Offset Reduced Diversions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1947	2,985	2,490	15,770	12,643	4,399	51,547	45,401	4,328	87	1,938	4,669	8,107
1948	8,962	9,232	9,949	18,878	4,814	10,283	2,805	168	0	0	0	0
1949	8,287	2,351	37	298	1,558	3,531	18,132	0	0	0	0	0
1950	0	0	3,823	4,407	0	0	0	0	0	0	0	0
1951	202	196	190	50	0	0	0	0	0	0	0	0
1952	54	0	0	252	7,018	3,530	0	0	0	0	0	0
1953	114	64	70	3,259	2,432	0	0	0	0	0	0	0
1954	0	0	0	39	0	0	0	0	0	0	0	0
1955	10	83	0	0	0	0	0	0	0	0	0	0
1956	120	58	13	0	0	0	0	0	0	0	0	0
1957	1,917	533	13	116	10,923	41,124	6,086	0	0	0	0	0
1958	21,343	20,745	23,003	24,667	41,249	40,457	6,759	0	0	0	0	0
1959	39	0	5,604	26,940	20,213	0	0	0	0	0	0	0
1960	1,154	4,424	13,562	20,563	8,301	1,964	0	0	0	0	0	0
1961	6	353	331	1,084	12,596	7,549	0	0	0	0	0	0
1962	12,409	21,820	29,882	23,366	314	14,605	471	0	0	0	0	0
1963	1,868	8,159	15,332	0	0	0	0	0	0	0	0	0
1964	40	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	16,273	19,646	27,393	3,293	31,975	27,658	26,059
1966	25,731	14,588	1,032	1,315	245	0	9	0	0	0	0	0
1967	53	53	578	199	0	8,281	8,285	79	0	0	0	0
1968	4,622	320	7,280	6,444	619	0	0	0	0	0	0	0
1969	252	77	643	728	51,415	53,996	15,310	50	0	0	0	0
1970	8,872	12,935	14,847	37,842	53,569	22,276	21,088	0	0	0	0	0
1971	12,597	12,623	20,462	14,397	6,726	0	0	0	0	0	0	0
1972	8,631	5,250	0	1,468	51	1,273	0	0	0	0	0	0
1973	25,250	39,479	28,741	25,714	43,852	20,815	103	1,316	0	2,392	21,293	15,259
1974	548	7,549	0	0	2,426	1,422	0	0	0	0	0	0
1975	15,797	20,340	3,131	13,087	0	29,429	1,365	0	0	0	0	0
1976	21,445	9,251	19,743	0	0	0	0	0	0	0	0	0
1977	4,936	2,129	6,443	3,336	0	0	0	0	0	0	0	0
1978	2,235	1,242	0	0	0	0	0	0	0	0	0	0
1979	5,359	17,581	1,288	0	0	0	0	0	0	0	0	0
1980	41,861	34,254	34,154	21,338	20,650	44,687	3,848	0	0	0	0	0
1981	18,502	6,405	6,273	13,970	1,997	26,143	0	0	0	0	0	0
1982	5,604	9,225	401	91	298	106	7,976	0	0	0	0	0
1983	29,260	27,762	28,202	9,984	11,211	13,363	12,282	0	0	18,084	21,649	0
1984	0	585	4,641	57,662	111,224	53,401	159	4,977	85,911	59,149	63,011	27,686
1985	19,978	1,499	6,634	213	40,873	41,242	213	0	0	0	0	0
1986	3,192	4,585	270	14,890	2,475	256	307	0	0	0	0	0
1987	18,965	20,920	14,492	5,595	22,174	26,340	395	0	0	0	0	0
1988	39,248	36,934	18,832	15,693	10,734	20,987	0	0	0	0	0	0
1989	30,859	13,496	11,747	106	8	0	0	0	0	0	0	0
1990	15,310	16,041	37,161	41,190	367	873	0	0	0	0	0	0
1991	18,531	25,700	4,712	2,836	0	35,043	0	0	0	0	0	0
1992	24,428	38,988	36,421	26,966	0	0	482	0	0	0	0	0
1993	27,814	25,826	24,200	23,379	90	248	129	0	0	0	0	0
1994	21,050	18,534	11,983	3,463	0	0	0	0	0	0	0	0