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Abstract
Colorado water users rely on water storage to capture spring and monsoon runoff for later beneficial use and seasonal water demands. A review of selected past (1977) and current (2000-2003) drought impacts on storage observed by spring, summer and fall measurements will be presented for all seven major river basins. Carry-over storage will be evaluated versus time for different geographies and water user segments in Colorado.

Contents:

Introduction

Runoff throughout Colorado is extremely variable from season to season as the winter snowpack melts each spring and from year to year as cycles of droughts and wet periods. Potential uses for stored water in Colorado are shown at right in Table 6-1.

Because the variability of supplies and demands are not in sync, surplus supplies exist at some times and in some locations while shortages inevitably occur at other times and locations. These shortages can be offset by a number of means, such as controlling demand by modifying operations, reducing demands through water conservation, moving the supplies from locations of surplus to locations of shortage, and storing surpluses for later use when shortages occur.

The focus of this chapter is on the use of storage in Colorado's river basins to balance supply and demand. Colorado water users rely on water storage to capture runoff from spring snowmelt and summer rains for later beneficial use and seasonal water demands. Storage facilities can take various forms, the most typical being the construction of earthen or concrete dams built to impound natural flow or diversions and form a lake or reservoir behind the dam. These can be built on a river or stream or built offstream with water diverted from another location into storage. Anther type of storage includes enclosed aboveground and underground water tanks, typically for supplying a small local use such as a farm or municipal area or neighborhood. Groundwater storage is also utilized, taking advantage of the natural storage characteristics in the underground aquifers in various parts of the State to store excess surface runoff by pumping via injection wells into the ground and later extracting those supplies as emergency or drought supplies. For this evaluation, surface storage (both onstream and offstream) is addressed as these represent the major type of storage used in Colorado to provide protection against drought.

Table 6-1: Potential Uses for Stored Water in Colorado

Irrigation of crops during the summer and fall.

Year-round **domestic and municipal** use that includes a summertime component for lawn irrigation and outdoor use.

Industrial needs such as water for processing and cooling.

Hydropower production.

Environmental needs such as minimum streamflows to maintain habitat.

Recreational needs to provide the flows needed to maintain or enhance uses such as river rafting, kayaking, and fishing.

Agricultural users have been utilizing reservoirs and ponds since the 1800's for storing spring runoff and irrigating crops in the summer and fall, when their direct flow water rights are insufficient to supply their needs. Storage facilities for irrigation range from small ponds impounding a few acre-feet of water for a single farmer to large projects such as Julesburg Reservoir and Lake Granby that impound tens of thousands to hundreds of thousands of acre-feet of water to supply irrigation water for hundreds of users.

Storage is used to regulate streamflow and produce hydropower, with small in-stream hydroelectric facilities such as the Idylwide facility on the Big Thompson River to the Shoshone Power Plant on the Colorado River and Blue Mesa Dam and Powerplant on the Gunnison River.

Storage has also been an integral part of municipal supply systems, with relatively small facilities such as Harper Reservoir serving the City of Louisville and large facilities such as Dillon Reservoir serving Denver.

Many storage projects, particularly the larger ones, meet multiple uses. Systems such as the C-BT Project provide water for agricultural, municipal, and hydropower use, as well as meeting needs of environmental and recreational interests. Coordination of operations between projects is also taking place, with programs such as the Colorado River Basin Coordinated Reservoir Operations used to enhance habitat in the 15-mile reach of the Colorado River.

Storage is also used for flood control, to temporarily capture runoff from both snowmelt and storms and control releases to prevent flooding downstream. Operation of storage for flood control generally conflicts with operations for drought protection, as the objective for flood control is to keep the storage facility empty to provide the maximum available capacity to capture flood waters, while the objective for drought protection is to keep the facility full to provide the maximum available supply to meet demands during drought. However, with appropriate operating policies, a storage facility can be operated for both objectives, an example of which is Chatfield Reservoir.

As noted previously, storage is used to capture surplus runoff for later use when demands exceed supply. The water stored at the end of a surplus period for use during a deficit period is referred to as "carryover storage". The amount of water carried over from season to season through wet and dry cycles is referred to as seasonal carryover storage. The amount of water carried over from one year to another is referred to as multi-year carryover.

To evaluate both the utilization of storage during drought cycles and the impact that storage has on water use, a component of the survey included requests for storage level contents of the respondents' systems. The reference years selected for the Drought & Water Supply Assessment were 1977 and 1998-2002, representing two significant recent drought periods years (1977 and 2000-2002) with relatively wet and average periods (1998-1999). Information on carryover storage was requested from each participant during these selected reference periods. The goal was to observe both drought impacts on storage and utilization of storage by spring, summer, and fall measurements for all seven major river basins and across the water use segments surveyed.

Available Data and Analysis

Data for this evaluation were available from the Natural Resources Conservation Service (NRCS), the State Engineer's Office, and the Division Engineer's offices throughout the State. The most comprehensive and complete data coverage over all basins and during our reference years was available from the NRCS and was used to provide the information for this assessment. The exception was 1977 where data were limited – a combination of sources were used to the extent possible.

The NRCS reports a summary of monthly storage contents in key reservoirs throughout Colorado. While not providing a complete picture of storage in each basin, the data can be used to provide a representative picture of the patterns of storage use during wet and dry cycles on a basin-wide and statewide basis.

The storage data were extracted from the NRCS reports for the six reference years for three key dates as shown at right.

Storage contents are shown graphically on Figures 6-1 through 6-7, corresponding to Water Divisions 1 through 7. Data not available are shown as "Not Reported" on the figures. Average lines are shown on each figure – these represent the monthly averages for only those six reference years (not a long term average) – to provide a relative comparison among the years. Runoff for each year is also classified in each basin. These classifications are defined using the major streamflow gages in each basin that are used by the State Engineers Office in characterizing runoff. Flows over the period of record were averaged for each gage, and those years where annual runoff was less than 85% of average were classified as below average, those where runoff was greater than 115% of average were classified as above average, and those between 85% and 115% of average were classified as average.

April 1: representing the beginning of the runoff season (note that data for 2003 were also available and are included in this evaluation).

July 1: representing the end of runoff when the reservoirs should be near their fullest.

November 1: representing the end of the irrigation season when the reservoirs should be near their lowest storage volumes and minimum operational storage.

Discussion of Results

Varying results were obtained from basin to basin. Utilization of storage during wet and dry cycles, as well as the potential for storing additional water was examined. Caution should be exercised in drawing conclusions from the results, as the information represents a broad-based view of storage in the basins, but it does not identify differences in storage utilization across the water use-segments surveyed or provide a clear view of potentially significant local hydrology and operational issues. Also, the operation of storage in the basins reported here only reflect historic and current levels of use, not the additional demands placed on storage to meet the future needs for which projects may have been built.

For instance, during a drought a municipal supplier can implement varying degrees of water conservation and drought management measures and manage its operations to target a reasonable level of carryover storage in its system for the end of the summer, providing protection against the drought continuing into the following year. Storage levels drawn down to 10, 20, or even 40 percent of capacity may reflect prudent system management rather than surplus storage water. However, an agricultural user may not have that flexibility – the water available in storage can mean the difference between getting a crop to harvest and losing the crop this year – and storage may be drawn to empty if necessary.

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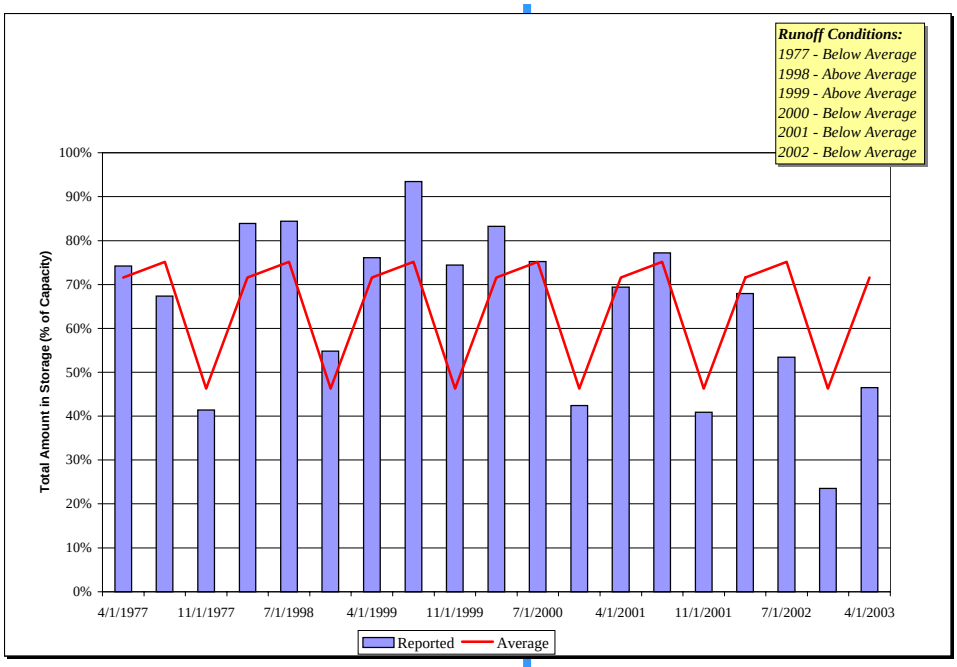
The seven Colorado basins are also very large in size and climatic and hydrologic conditions can vary widely in any given year not only across the State, but within each basin, affecting both the needs for stored water to supplement natural runoff and the availability of surplus runoff to store for later use. As an example, within the South Platte River basin alone, the NRCS June 2003 forecasts of spring runoff for this year range from only 35 percent of average for Antero Reservoir in South Park to 104 percent of average on Boulder Creek near Orodell.

With these facts in mind, some general observations can be made regarding the utilization of storage in Colorado's river basins:

- ***Division 1 – South Platte River:*** Utilization of storage is significant during periods of drought, with the most significant

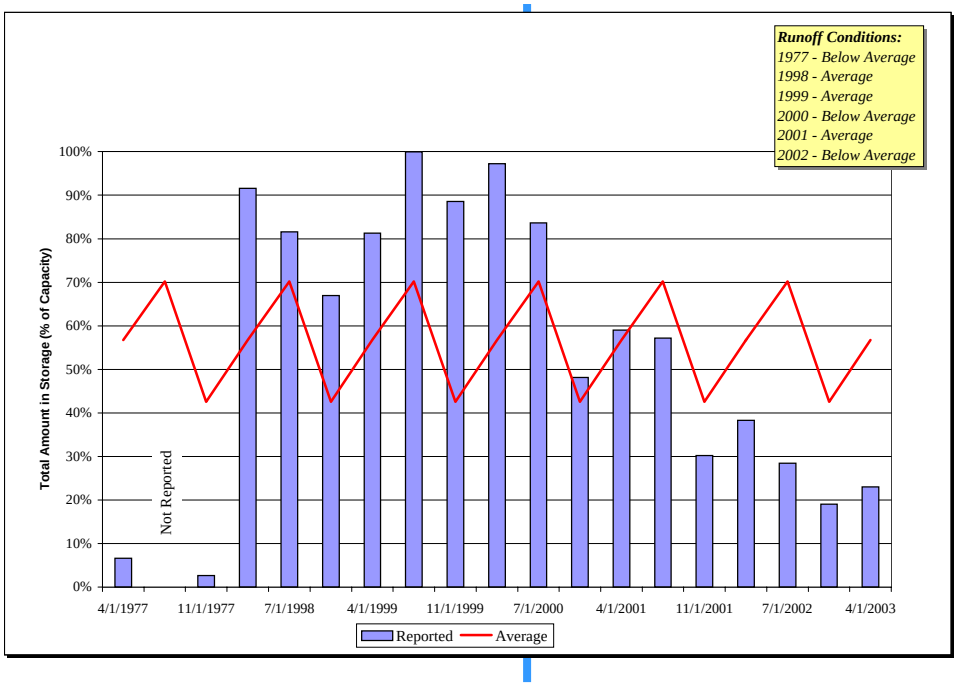
drawdown occurring in 2002-2003. Prudent management of supplies and storage in 2002 maintained an overall minimum storage level of 24% of capacity at the end of 2002. During high runoff years, storage levels ranged in the 83-93% of capacity level. Though not reflecting full conditions overall, it is likely that some areas of the basin did reach full capacity and could have stored more water during these periods with additional capacity.

Figure 6-1: Division 1 Carryover Storage



- ***Division 2 – Arkansas River:*** Significant drawdowns of storage occur during periods of drought, indicating a high degree of reliance on storage during these periods. Storage levels below 10% were recorded in the 1977 drought, and levels below 20% during the 2002 drought, indicating a significant reliance on storage during drought and the probable full utilization of available capacity. Furthermore, storage levels have exceeded 90% and reached 100% during high runoff periods, indicating the potential availability of runoff to fill additional capacity.

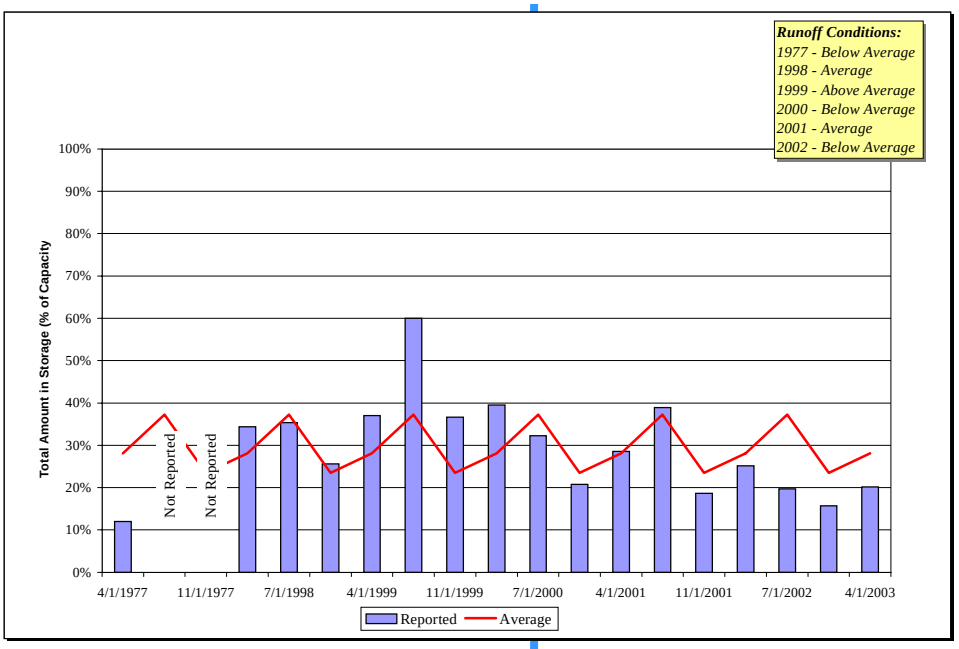
Figure 6-2: Division 2 Carryover Storage



- ***Division 3 – Rio Grande River:*** The results indicate a situation that differs greatly from the other basins. While storage is utilized in the basin, there is not a major difference in usage between wet and dry years. There does not appear to be sufficient runoff to fill the capacity

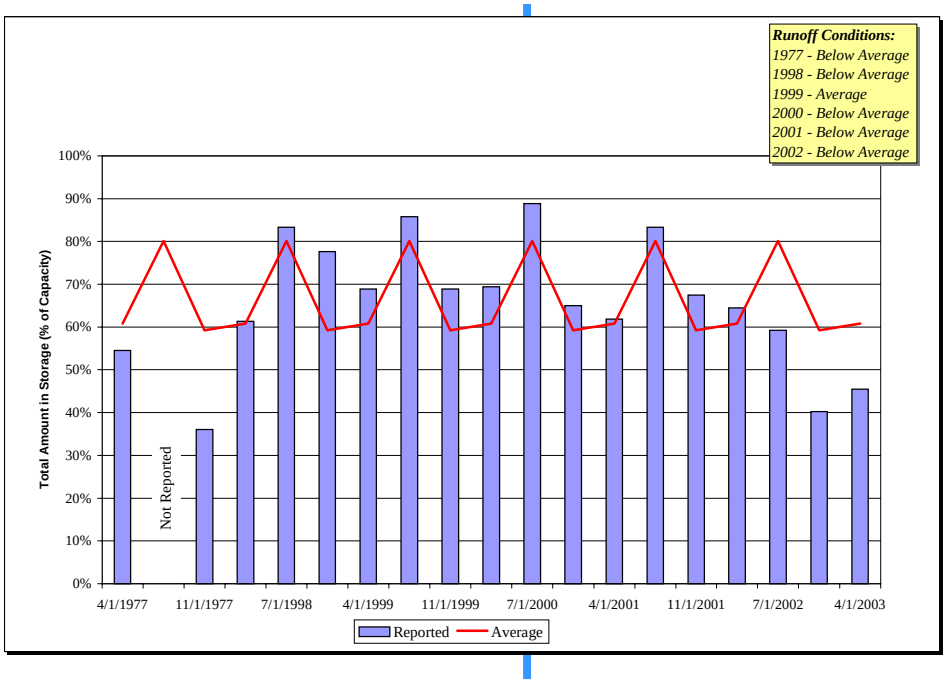
currently available in the basin – whether due to physical availability, legal compact requirements, or a combination of these factors. Storage levels generally run extremely low at all times, ranging from 10-40% of capacity in most years, and exceeding 50% in only one year. There does not appear to be a benefit in increasing storage in the basin.

Figure 6-3: Division 3 Carryover Storage



- ***Division 4 – Gunnison River:*** The Aspinall Unit of the Colorado River Storage Project represents over 75% of the total storage capacity monitored in the basin by the NRCS, potentially tempering any conclusions regarding other available storage in the basin. From the results presented, storage is utilized in the basin during periods of drought, with large drawdowns occurring in both 1977 and 2002. Storage appears to be efficiently managed in the basin and there appears to be sufficient storage in the basin to meet current usage levels and possibly some additional demands during significant droughts, as storage did not range below 36-40% of capacity. The management of storage for hydropower production by the Aspinall Unit may also be reflected in these relatively high storage levels. During high runoff years, storage levels ranged in the 83-89% level. Though not reflecting full conditions overall, it is likely that some areas of the basin did reach full levels and could have

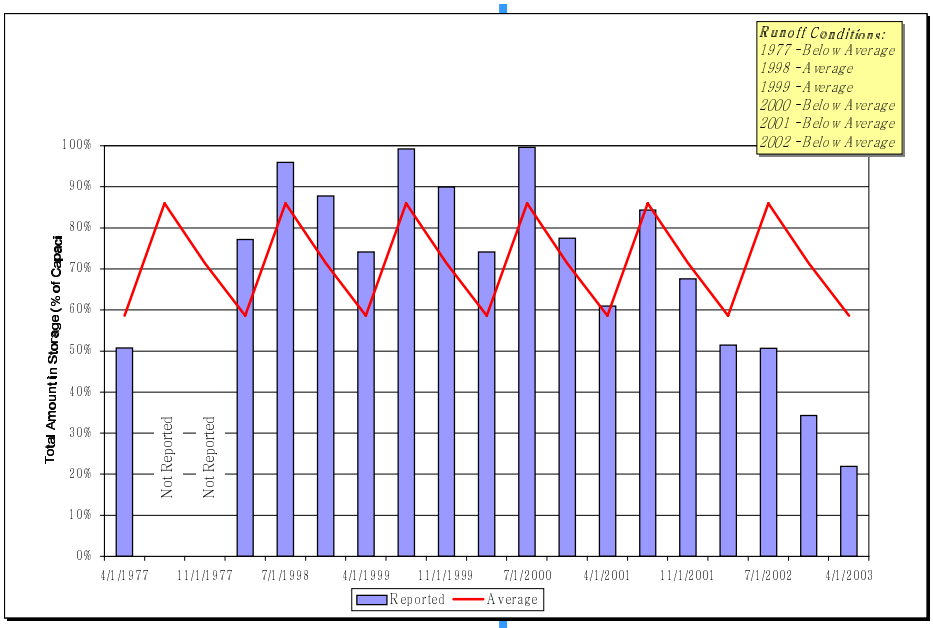
Figure 6-4: Division 4 Carryover Storage



stored more water during these periods with additional capacity.

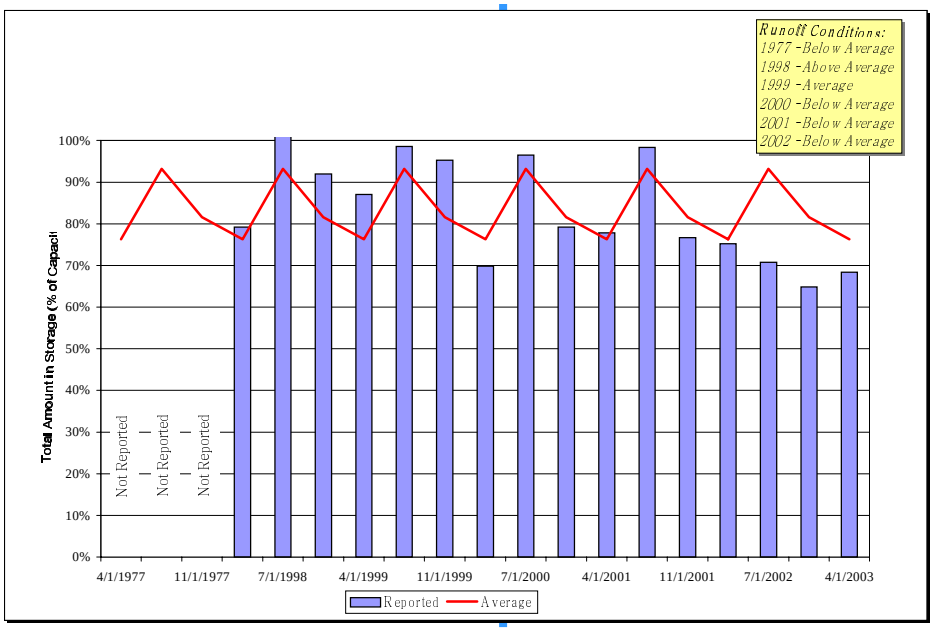
- ***Division 5 – Colorado River:*** Storage levels varied significantly in this basin during the reference years examined. Storage has been heavily utilized in the basin during periods of drought. Even though full status was achieved in July 2000, storage levels dropped to nearly 20% of capacity by April 2003, indicating nearly full utilization of existing storage. Without prudent management by operators throughout the basin, storage depletions could have been much greater. Storage use is likely intensified by the high level of transmountain use in the basin, with existing storage providing supplies to both west and east slope users. Storage levels of 90% capacity were reached in two years and 100% in another two years. This indicates that while storage is heavily utilized, there is a potential benefit of additional storage in the basin with available runoff.

Figure 6-5: Division 5 Carryover Storage



- ***Division 6 – Yampa/White Rivers:*** Storage is utilized in these basins, with greater drawdowns occurring in drought years than in high runoff or average years. However, storage appears to be efficiently managed and potentially underutilized overall, with levels never dropping below 65% during the 2002 drought. Full and nearly full levels were also reached in four of the years examined. These results indicate that existing storage could be more fully utilized, and there is a potential benefit of additional storage

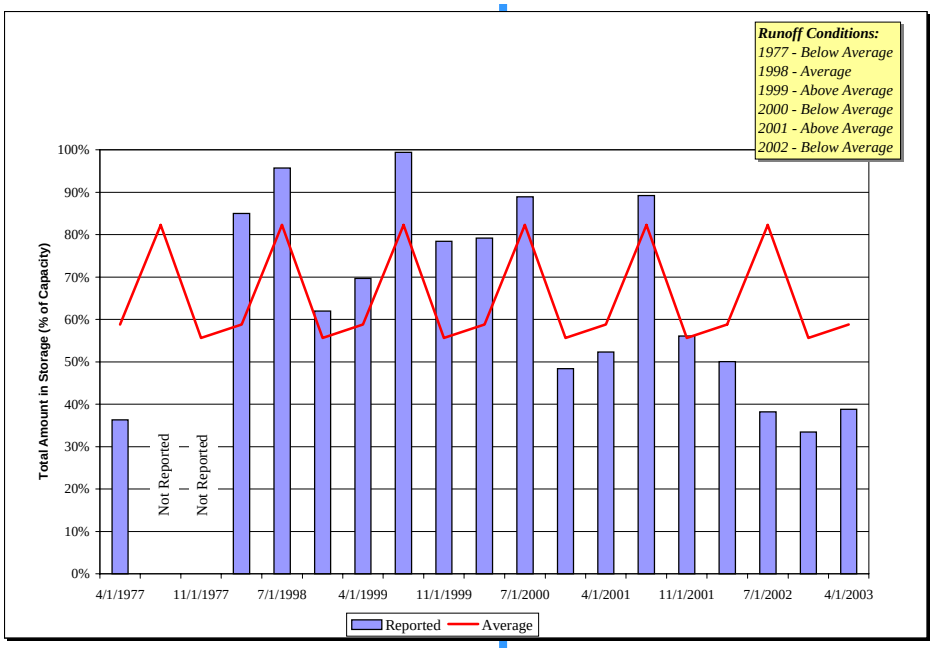
Figure 6-6: Division 6 Carryover Storage



in the basin to meet demands beyond current levels.

- ***Division 7 – San Juan/Dolores Rivers:*** Storage levels varied significantly in this basin during the reference years examined. Storage has been heavily utilized in the basin during periods of drought. Even though full status was achieved in July 1999, storage levels dropped to 33% of capacity by November 2002, indicating that additional utilization of existing storage is limited. Storage levels of 89-100% capacity were reached in four years. This indicates that while storage is heavily utilized, there is a potential benefit of additional storage in the basin.

Figure 6-7: Division 7 Carryover Storage



Conclusions

Water planners and managers face numerous challenges in identifying the need for and planning of their water supplies. Ultimately, the challenge faced is to provide a reliable water supply to their users, balancing the current and future needs of their users with the cost of meeting those needs at an acceptable level of risk, including risk to the ecosystem and to the environment. With the extreme variability of runoff in Colorado from season to season and year to year, storage provides a means of managing that variability and meeting the need for water. Given the various and variable uses of storage, risks can be controlled and managed with proper planning and evaluation. Given the complexity, cost, and time required to build reservoirs, storage projects are typically planned and built with future needs in mind on a local, and increasingly, on a regional scale.

From this statewide and basin-wide assessment, storage is obviously an important component of current and future water supplies throughout Colorado, though levels of usage can vary significantly from basin to basin. The potential for increasing the utilization of existing storage is greatest in the Yampa/White and Gunnison River basins. In some divisions, there is also the potential for capturing additional water to enhance the utilization of supplies – this potential

exists in all but the Rio Grande basin, and is most significant in the Colorado, Yampa / White, and San Juan / Dolores basins.

While storage capacity does not create additional water supplies, both the increased utilization of existing storage capacity and the development of additional capacity can improve the overall reliability of the water supplies available throughout Colorado and help ensure the present and future water supply needs of the State can be met.