UPPER RIO GRANDE WATER OPERATIONS MODEL
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INTRODUCTION

The accounting of reservoir losses and storage described in this document is used at Heron, El Vado, Abiquiu, Cochiti, Jemez Canyon and Elephant Butte Reservoirs and includes (1) identification and allocation of losses associated with construction and operation of the reservoir and (2) isolation of losses associated with importation and management of San Juan-Chama Project water. The processes of identifying and allocating losses are handled simultaneously under three loss conditions: pre-reservoir, present, and hypothetical. Loss determinations are similar yet distinct for each reservoir. The approved loss rates for transportation of San Juan-Chama Project water are also described.

The pre-reservoir condition assimilates the losses that would have occurred in the river channel and its surrounding area within the area defined by the high-water boundary of the reservoir. Present condition addresses how loss conditions actually are now (without consideration of any other superimposed conditions). Hypothetical condition represents how losses would look if only Rio Grande waters were stored in the reservoir.

The Bureau of Reclamation (USBR) has established procedures that have been approved by the Rio Grande Compact Commission to account for San Juan-Chama Project water in the Rio Grande Basin. The intent of these accounting procedures is to ensure the native Rio Grande waters are not impacted by San Juan-Chama water storage and movement throughout the system. This water accounting system determines the portions of the reservoir losses that should be charged to the San Juan-Chama and Rio Grande “pools” within a given reservoir and travel losses through the river system.

Previously, these procedures were done with computer programs that were coded in FORTRAN for each reservoir and commonly referred to as the “daily programs”. The FORTRAN code was then ported over to C++ to run in RiverWare® as Account Loss methods that can be selected when creating reservoir(s) objects. The subsequent discussions and equations describing the San Juan-Chama and Rio Grande accounting procedures are taken from USBR’s water accounting reports and daily programs and RiverWare Account Loss Methods codes.

The Physical Accounting Model primarily solves for reservoir inflow, and then calculates all additional loss and storage data to report and store in the model and database. This is the same operation that the USBR daily programs had performed. The Physical Accounting Model in RiverWare, however, improves the accounting process by linking the releases of San Juan-Chama water to the inflows of the next downstream reservoir. In the process, it creates (positive or negative) local inflows between reservoirs, representing the unaccounted-for differences between what leaves the upstream reservoir and what arrives downstream. The Physical Accounting Model calculates total water storage, Rio Grande storage, San Juan-Chama Project water storage, and in some reservoirs, sediment deposition and sediment content effects.

RIVER ACCOUNTING

Loss rates and travel time lags for San Juan-Chama water in the reaches between Heron Dam and Elephant Butte Reservoir are shown in **table 1**. The Rio Grande Compact Commission has approved these loss rates. The difference between the physical loss calculated by the total water simulation and the loss from the San Juan-Chama water will be accounted for as Rio Grande loss.

Table 1. San Juan-Chama Project water loss rates and travel time lags

Reach	Loss (%)	Lag
Heron to El Vado	0.00	0 day
El Vado to Abiquiu	1.10	1 day
Abiquiu to Otowi	0.90	1 day
Otowi to Cochiti	0.33	0 day
Otowi to mouth of Jemez R.	0.35	0 day
Cochiti to Elephant Butte:**		
Jan	3.30	3 days
Feb	3.80	3 days
Mar	5.20	3 days
Apr	6.50	3 days
May	7.20	3 days
Oct	4.60	3 days
Nov	3.70	3 days
Dec	3.30	3 days

** There are no official San Juan-Chama Project loss rates from Cochiti to Elephant Butte for the months of June through September.

HERON RESERVOIR

Heron Reservoir is the principal storage/supply feature of the San Juan-Chama Project, and is operated in compliance with the Rio Grande Compact. Three basic principles control the water release schedule for Heron Reservoir. The first is that no Rio Grande water is to be stored in Heron, second is the authorized development of San Juan-Chama Project supplemental irrigation and municipal and industrial water demands that increase depletion of the Rio Grande. These depletions are offset by releases of San Juan-Chama water from Heron Reservoir sufficient to assure no residual effects to natural waters of the Rio Grande from project operations.

The third principle is that San Juan-Chama contractors are not allowed to carryover their annual allocations into the next calendar year. Contracted water not called for by December 31 remains in Heron Reservoir as part of project supply and no longer belongs to the individual contractor. In the past, USBR negotiated temporary waivers with contractors that allow carryover until April 30 in order to provide release rates on the Rio Chama that enhance the fishery between El Vado and Abiquiu Reservoirs during the winter and provide flexibility in managing river flows. The no-carryover stipulation results in various contractors seeking storage in reservoirs downstream from Heron for their unused water. El Vado, Abiquiu, Jemez Canyon, and Elephant Butte Reservoirs have been used for storage of San Juan-Chama waters. Another factor that influences Heron releases is ice cover on the reservoir and the resulting safety issues. If Heron is drawn down quickly when iced over or nearly completely iced over, hazardous conditions develop. Releases are terminated until conditions are safe. During late March or April, any San Juan-Chama Project water not released because of unsafe winter operation conditions is released at a time when it will meet the same purposes as if it had been released during the winter months, provided the necessary waivers have been granted.

The Natural Resources Conservation Service/National Weather Service-coordinated runoff forecast is used to estimate the period of time during spring runoff that the flow of the Rio Chama is expected to exceed channel capacity below Abiquiu Reservoir and thus prevent a release of San Juan-Chama Project water from Abiquiu Reservoir. San Juan-Chama releases are generally avoided after April due to (normally) sufficient natural flows coming into summer. Unless specifically directed by the contractor or by the New Mexico Interstate Stream Commission, replacement deliveries are held for flow supplementation later in the year.

INFLOW CALCULATIONS

Inflow to Heron Reservoir consists of imported San Juan-Chama Project water diverted at Rio Blanco, Little Oso, and Oso, delivered through Azotea Tunnel (measured at the tunnel outlet) and Rio Grande water from Willow Creek, which are conjointly measured at the gage Willow Creek above Heron Reservoir. Rio Grande inflow also includes flow from the intervening area below the gage and the area around the reservoir such as Horse Lake Creek.

ACCOUNTING MODEL INFLOW

In the Physical Accounting Model, preliminary calculations for determining Rio Grande inflow to Heron Reservoir are performed daily, but the final determination of Rio Grande inflow is made at the end of each month for the following three reasons:

1. The ratio inflow method (see below) was initially derived as a monthly method, making the amount of Rio Grande pool uncertain until after the last day of the month.
2. The San Juan-Chama Project portion of Rio Grande Compact accounting is done on a monthly basis.
3. During much of the year, water from Heron Reservoir is released near the end of each month. To operate the reservoir at a lower cost and to reduce the number of visits to Heron Dam, fewer but larger amounts of water are released.

Several different methods are used to compute Rio Grande inflow for the Physical Accounting Model. The method or combination of methods that provides the most meaningful estimate of Rio Grande inflow is then selected on the basis of daily-accumulated values at the end of the month. Determining which method(s) governs is also attempted throughout the month using the cumulative daily values up to the date of the computations. The methods include ratio inflow, seepage from the dam, and net end-of-month gain (the term used in water accounting reports). Rio Grande inflow is finally determined at the end of the month.

MASS BALANCE EQUATION

The general mass balance equation for reservoirs is in the following form:

$$S_t - S_{t-1} - I - P_t + E_t + O = 0$$

where:

S_t = total storage today, in acre-feet;

S_{t-1} = total storage yesterday, in acre-feet;

I = total inflow to reservoir, in acre-feet;

P_t = total precipitation, in acre-feet;

E_t = total evaporation, in acre-feet per day; and
O = total outflow from the reservoir, in acre-feet per day.

Because Heron Reservoir has two sources of water, the inflow and outflow parameters of the equation can each be separated into two components as follows:

$$I = I_{rg} + I_{sj}$$

$$O = O_{rg} + O_{sj}$$

where:

I_{rg} = Rio Grande inflow to the reservoir, in acre-feet per day;
I_{sjc} = San Juan-Chama inflow to the reservoir, in acre-feet per day;
O_{rg} = Rio Grande outflow from the reservoir, in acre-feet per day; and
O_{sjc} = San Juan-Chama outflow from the reservoir, in acre-feet per day.

The only storage allowed in Heron Reservoir is San Juan-Chama water, so the storage parameter is assumed to be only the total storage of the reservoir. Therefore, the mass balance equation becomes:

$$S_t - S_{t-1} - I_{rg} - I_{sj} - P_t + E_t + O_{rg} + O_{sj} = 0$$

Solving for the Rio Grande inflow component results in the following equation:

$$I_{rg} = S_t - S_{t-1} + O_{rg} + O_{sj} + E_t - P_t - I_{sj}$$

Because of the large storage volume of Heron Reservoir (400,000 acre-feet) compared to the small natural inflow volume (average of 2000 acre-feet per month), the mass balance equation often results in negative Rio Grande inflows. Therefore, other methods for determining Rio Grande inflow were developed. These methods include ratio inflow, seepage from the dam, and net end-of-month gain.

RATIO INFLOW METHOD

The ratio inflow method attempts to use stream-gage information to compute Rio Grande inflow. San Juan-Chama inflow is known because the flow from Azotea Tunnel is measured at the outlet, and an established reach loss (Azotea outlet flow times 0.002) is applied for the reach from the tunnel to the Willow Creek above Heron gage (“above Heron gage”). Subtracting the San Juan-Chama component from the above Heron gage results in the natural flow volume at the above Heron gage. This resulting natural flow volume at the gage is adjusted by a correlation or ratio factor (thus the term “ratio method”) to account for intervening flow between the gages above and at Heron Dam. The ratio factors were developed on the basis of a study of monthly flows at the gages above Heron and Willow Creek at Parkview from 1943 to 1970. The ratio factors determined were 1.20 for “tributary flows above” greater than 360 acre-feet per month and 2.46 for “tributary flows above” less than or equal to 360 acre-feet per month. The daily calculations for the ratio method are summarized in the following equations:

$$Q_{sj\,calc} = Q_{az} \bullet 0.998$$

$$I_{rg\,tributary} = Q_w - Q_{sj_{calc}}$$

where:

$Q_{sj_{calc}}$ = calculated San Juan-Chama flow at the Willow Creek gage, in acre-feet per day;

Q_{az} = gaged flow from Azotea Tunnel, in acre-feet per day;

$I_{rg_{tributary}}$ = tributary Rio Grande inflow at the Willow Creek gage, in acre-feet per day; and

Q_w = gaged flow at Willow Creek above Heron, in acre-feet per day.

$$I_{rg\,ratio\,low} = I_{rg\,tributary} \bullet (2.46)$$

$$I_{rg\,ratio\,high} = I_{rg\,tributary} \bullet (1.2)$$

where:

$I_{rg\,ratio\,low}$ = Rio Grande low-ratio inflow, in acre-feet; and

$I_{rg\,ratio\,high}$ = Rio Grande high-ratio inflow, in acre-feet.

Operationally, a determination of Rio Grande inflow is needed before the end of the month. The choice of which ratio inflow to use is based on the value determined by the following equation, rather than 360 acre-feet.

$$Q_{test} = (360/30) \bullet CD$$

where:

Q_{test} = value to test for ratio, in acre-feet; and

CD = day of the month the calculations are made.

After the ratio inflow is selected, the daily values are summed; if the result is negative, the value of the ratio inflow is set to zero (this rule is applied only monthly or to the daily cumulative value in the daily program). This method also has inherent problems in that it relies on streamflow measurements at the Azotea outlet and the gages above Heron to produce accurate results. One or both gages may be off regarding the relative magnitude of the real difference of the flows, producing questionable results (for example, negative Rio Grande inflows).

SEEPAGE METHOD

After the initial filling of Heron Reservoir, seepage from the reservoir was measured. This seepage was confined to a channel and was of sufficient quantities to be measurable. Leading agencies agreed that this seepage be accounted for as native water because to account for it as San Juan-Chama water would result in releases of water during times of no demands for the water and no account to charge the releases to. Algorithms were developed to predict seepage using water-surface elevation. The seepage method (adopted in 1988) considers seepage as part of the natural release from the reservoir. Because no Rio Grande storage is allowed in Heron Reservoir, Rio Grande inflow that enters the reservoir should be at least equal to the amount of Rio Grande outflow that is due to seepage.

Seepage from the reservoir is calculated by the equation:

$$Seep = (Elev_r - 7100) \bullet 0.02134 + 0.76$$

where:

$Seep$ = seepage from the reservoir, in cubic feet per second (cfs); and

$Elev_r$ = reservoir elevation, in feet.

Note: When the reservoir water-surface elevation is below 7064 feet, the computation produces negative results, in which case the seepage value is set to zero.

NET END-OF-MONTH GAIN METHOD

The net end-of-month gain method attempts to compute unmeasured Rio Grande inflow during the month and is a variation of the Heron Reservoir mass balance equation. The calculations for this method are made daily. The results are summed for an end-of-month determination, or if the month is not over, a “cumulative to date” are determined.

Rearranging the general mass balance equation and substituting the inflow from the ratio inflow gives:

$$S_t - S_{t-1} + O_{rg} + O_{sjc} - I_{sjc} - I_{rg\,ratio} - P_t + E_t = 0$$

The total precipitation (P_t) that falls on the reservoir is divided up as shown in the following equation. One portion of precipitation is labeled “Rio Grande” and consists of the amount of precipitation that would have returned to the river system and would not have been lost to evapotranspiration or soil moisture before the reservoir was built. The other portion of precipitation is labeled “San Juan-Chama” and is the amount of precipitation that would have been lost to the river system if the reservoir were not there. This pre-reservoir loss of precipitation is known as “effective precipitation.” Effective precipitation is the portion of precipitation that evapotranspiration consumes or that infiltrates into the soil. Effective precipitation is computed on the basis of accumulated actual precipitation for the month. **Table 2** provides information for effective precipitation for Heron Reservoir.

$$P_t = P_{eff} + P_{rg}$$

where:

P_{eff} = effective precipitation (San Juan-Chama precipitation), in acre-feet per day; and

P_{rg} = Rio Grande precipitation, in acre-feet per day.

Substituting the parts of precipitation gives:

$$S_t - S_{t-1} + O_{rg} + O_{sjc} - I_{sjc} - I_{rg\,ratio} - P_{eff} - P_{rg} + E_t = 0$$

If one considers the Rio Grande portion of precipitation as part of the total reservoir end-of-day gain, the previous equation can be rearranged to:

$$S_t - S_{t-1} + O_{rg} + O_{sjc} - I_{sjc} - I_{rg\,ratio} - P_{eff} + E_t = G_{ed}$$

where:

G_{ed} = end-of-day gain, in acre-feet.

The net end-of-day gain is the Rio Grande gain on Heron Reservoir. To remove the San Juan-Chama component of gain, the precipitation that is considered San Juan-Chama (the effective precipitation) is removed from the equation. Because only San Juan-Chama water is allowed to be stored in the reservoir, the only evaporation is San Juan-Chama water. Therefore, evaporation is also removed from the Rio Grande gain equation, leaving the following equation for net end-of-day gain.

$$S_t - S_{t-1} + O_{rg} + O_{sjc} - I_{sjc} - I_{rg\ ratio} = NG_{ed}$$

where:

NG_{ed} = net end-of-day gain, in acre-feet.

As can be seen in the above equation, the Rio Grande gain (net end-of-day gain) is any Rio Grande component of precipitation plus any unaccounted for gains on Heron Reservoir. This method can also result in negative end-of-month storages, indicating that this method can be invalid.

Table 2. Effective precipitation

Precipitation through end of month (inches)	Heron	El Vado	Abiquiu	Cochiti	Jemez	Elephant Butte
0 to 1	95%	100%	100%	95%	95%	100%
>1 to 2	90%	100%	100%	90%	90%	100%
>2 to 3	82%	100%	100%	82%	82%	100%
>3 to 4	65%	50%	50%	65%	65%	100%
>4 to 5	45%	50%	50%	45%	45%	100%
>5 to 6	25%	50%	50%	25%	25%	100%
>6	5%	50%	50%	5%	5%	100%

DETERMINATION OF RIO GRANDE INFLOW

Once Rio Grande inflow has been computed using the various methods, a decision is made, through a series of logical expressions, on which method or combination of methods provides the most accurate estimate. When Heron Reservoir inflow is calculated before the end of the month, the cumulative totals to the calculation date are used with the logical expressions.

The logical expressions used to determine Rio Grande inflow are given below. (Note that a new variable is introduced in the USBR annual water accounting report (Table 1 - Apparent inflow to Heron Reservoir, column 6), “tributary inflow within” Heron Reservoir. This variable presents the result of the logical tests and is assigned the value of seepage, net end-of-month/day gain, or 0).

If NG_{ed} < 0

then NG_{ed} = 0

If NG_{ed} > $Seep$

then I_{within} = NG_{ed}

else $I_{within} = Seep$

If $NG_{ed} = 0$ and $I_{rg\ ratio} > Seep$

then $I_{within} = 0$

If $I_{rg\ ratio} > Seep$

then $I_{RG} = I_{rg\ ratio} + I_{within}$

else $I_{RG} = I_{rg\ ratio}$

where:

I_{within} = tributary inflow within Heron reservoir, in acre-feet.

The combination methods are referred to as hybrid methods, which are actually variations of mass balance inflow. Because the ratio inflow method is part of each hybrid method, it will be referenced by the other component of the method--that is, the seepage hybrid method (seepage plus ratio) or the net end-of-month/day gain hybrid method (net end-of-month/day gain plus ratio).

The logical expressions can also be represented without introducing the “tributary inflow within” variable and arranged as follows. (This seems to make which method is selected to estimate Rio Grande inflow to Heron Reservoir more intuitive.)

If $Seep > NG_{ed}$, then

If $Seep \geq I_{rg\ ratio}$, then

$I_{RG} = Seep$

else

If $NG_{ed} \leq 0$, then

$I_{RG} = I_{rg\ ratio}$

else

$I_{RG} = Seep + I_{rg\ ratio}$

else

If $Seep \geq I_{rg\ ratio}$, then

$I_{RG} = NG_{ed}$

else

$I_{RG} = NG_{ed} + I_{rg\ ratio}$

Summarizing the above logical expressions:

1. Use the largest result from the three primary methods (ratio inflow, seepage, net end-of-month/day gain) when at least one of the other methods is less than seepage and (or) the net end-of-month/day gain method produces a negative result.

2. Use the result from the seepage method when it is greater than both the ratio inflow and net end-of-month/day gain methods (that is, Rio Grande inflow is never less than Rio Grande release determined by the seepage method).

3. Use the result from the ratio inflow method when it is greater than the seepage method and the net end-of-month/day gain method results in negative values. This does not produce the same result as testing only that the ratio inflow method is greater than both the seepage and net end-of-month/day gain methods. The net end-of-month/day gain method must be less than or equal to zero for the ratio inflow method to be invoked.

4. Use the result from the end-of-month/day method when it is greater than the seepage method and the seepage method is greater than the ratio inflow method. This does not produce the same result as testing only that the end-of-month/day method is greater than both the seepage and ratio inflow methods. The seepage method must be greater than the ratio inflow method for the net end-of-month/day gain method to be invoked.

5. Use one of the hybrid methods when both the ratio inflow and end-of-month/day methods provide positive results and at least one of the methods is greater than seepage.

6. Use the result from the seepage hybrid method when the seepage method is greater than the net end-of-month/day method and statement 5 is true.

7. Use the result from the end-of-month/day method when it is greater than the seepage method and statement 5 is true. Note that this is the same as the general Heron Reservoir mass balance equation, computing Rio Grande inflow minus the net evaporation term.

STORAGE AND LOSS CALCULATIONS

All losses on Heron Reservoir are losses from the San Juan-Chama pool. There are no losses from the temporary Rio Grande pool. The equations for San Juan-Chama loss from Heron Reservoir are:

$$S_{rg_t} = S_{rg_{t-1}} - O_{rg} + I_{rg}$$

$$S_{sjc_t} = S_T - S_{rg_t}$$

$$NL_{sjc} = \left(S_{sjc_{t-1}} - S_{sjc_t}\right) + I_{sjc} - O_{sjc}$$

$$NL_{phy} = E_t - P_t$$

An adjustment variable reconciles the difference between total water loss calculations and San Juan-Chama loss calculations:

$$NL_{adj_t} = NL_{phy_t} - NL_{sjc_t}$$

This adjustment factor reconciles any unidentified loss due to evaporation or inaccuracies in gage measurements.

EL VADO RESERVOIR

El Vado Dam was originally constructed to provide conservation storage for a supplemental irrigation supply for MRGCD lands along the Rio Grande from Cochiti Reservoir to below Socorro, New Mexico. Because El Vado Dam was constructed after 1929 (completed in 1935), operation of the reservoir for storage and release of Rio Grande water is subject to the Rio Grande Compact. Water imported into the Rio Grande Basin through the San Juan-Chama Project and stored in El Vado Reservoir is not subject to the storage and release restrictions of the Rio Grande Compact.

OPERATION FOR RIO GRANDE WATER

The basic concept in operating El Vado Reservoir involves storage of natural inflow that exceeds current MRGCD and other needs below El Vado Dam. The major storage season is during spring runoff; storage can then be released during the irrigation season to users in the Middle Rio Grande Valley as needed.

RESTRICTIONS OF THE RIO GRANDE COMPACT

Article VII of the Rio Grande Compact provides that no Rio Grande water in El Vado Reservoir can be stored when usable water in project storage (storage in Elephant Butte and Caballo Reservoirs) is less than 400,000 acre-feet. Article VI provides that any Rio Grande water stored in El Vado Reservoir must be held in storage to the extent of New Mexico's accrued debit under the compact.

WATER RIGHT CONSTRAINTS ON OPERATION FOR RIO GRANDE WATER

El Vado is operated to store native water for the six Middle Rio Grande Pueblos of Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta. The Bureau of Indian Affairs and the USBR compute the amount of storage required, and Indian storage water is released only when the natural flow of the Rio Grande is insufficient to adequately supply irrigation to 8847 acres of Indian lands.

Additionally, no native water can be stored in El Vado Reservoir when to do so would deprive acequias along the Rio Chama downstream from El Vado of water to which they are entitled. In 1971 the New Mexico State Engineer required that El Vado Reservoir be operated during the irrigation season to pass all natural flow of the Rio Chama up to 100 cfs, as measured below Abiquiu Dam, during the irrigation season.

MULTIPLE RIO GRANDE ACCOUNTS IN EL VADO

In 2003, an Emergency Drought Water Agreement (EDWA) was implemented that allowed Rio Grande storage in El Vado (other than for Indian Storage requirements), even though operations of Rio Grande basin reservoirs are under Article VII of the compact. The EDWA allowed for storing several types of Rio Grande water (based on relinquishing some of New Mexico’s credit water under the compact) for use by the Middle Rio Grande Conservancy District (MRGCD) and supplemental water for endangered species needs.

This agreement necessitated accounting for both of the EDWA types of water, along with separating the Indian Storage requirement and a generic Rio Grande account, in the URGWOM accounting, water operations and planning models. This required a modification to the Storage Account Gain Loss method for El Vado to allow for more than one Rio Grande account and proportion the loss to each account. Rules also needed to be developed (for the water operations and planning models) to move water into the accounts and release the water for uses downstream. A number of rules and functions were created or modified to model these new accounts.

There are now four Rio Grande accounts in the El Vado object (in the accounting, water operations and planning models); IndianStorage, MRGCDDrought, RioGrande and SupplementalESA. Water is placed into the accounts based on the following; the Indian Storage pool is the first to be filled up to its required amount, then the MRGCDDrought and SupplementalESA pools are proportionally filled simultaneously up to the EDWA allowance for each account. Releases from the MRGCDDrought account are delivered to help meet MRGCD demands in the middle valley. Releases from the SupplementalESA account are used to meet target flows in the middle valley (i.e., at Central and San Acacia). The IndianStorage water is released to meet Indian demand when the natural flow at Otowi is not adequate to meet the demand and needs to be supplemented from storage.

When operations are not restricted by Article VII of the compact, Rio Grande water is stored in the RioGrande account for use by MRGCD, as has typically been done in the past. The IndianStorage account is treated the same as always as mentioned above (is filled first and released for Indian demand). The other two Rio Grande pools would not have any storage under normal conditions (when not under Article VII).

OPERATION FOR SAN JUAN-CHAMA WATER

El Vado Reservoir operation is affected by the San Juan-Chama Project in two ways. First, San Juan-Chama Project water released from Heron Dam for use downstream from El Vado Reservoir is simply passed through. Second, large volumes of San Juan-Chama Project water in El Vado Reservoir may be stored for extended periods of time. The MRGCD has contracted for 20,900 acre-feet per year of San Juan-Chama Project water and maintains as much of this water in El Vado Reservoir as conditions permit. In addition, the MRGCD has contracted with various contractors of San Juan-Chama Project water to allow for storage of their water in El Vado Reservoir.

RIO GRANDE AND SAN JUAN-CHAMA PROJECT STORAGE CALCULATIONS

Total water storage for El Vado Reservoir is determined using elevation-capacity tables. This total storage is divided into Rio Grande and San Juan-Chama Project storage. The latter is further divided into individual contractor accounts. The general equation for calculation of San Juan-Chama water storage is:

$$S_{sjc_t} = S_{sjc_{t-1}} + I_{sjc_t} - O_{sjc_t} - NL_{sjc_t}$$

where:

S_{sjc_t} = San Juan-Chama storage today, in acre-feet;

$S_{sjc_{t-1}}$ = San Juan-Chama storage yesterday, in acre-feet;

I_{sjc_t} = San Juan-Chama inflow, in acre-feet; and

O_{sjc_t} = San Juan-Chama outflow, in acre-feet.

The term NL_{sjt} used here is not the same term as calculated for Heron Reservoir, but determined as described under the heading Net Losses on page 15.

The equation for calculating Rio Grande storage is:

$$S_{rg_t} = S_{T_t} - S_{sjc_t}$$

where:

S_{rg_t} = Rio Grande storage, in acre-feet; and

S_{T_t} = total physical storage, in acre-feet.

LOSS CALCULATIONS

The generalized physical accounting loss calculations are described in the following sections. This procedure is repeated in similar form for the remaining reservoirs in the model.

In general, losses are calculated for three different conditions: (1) natural losses with no reservoir (pre-reservoir), (2) losses with only Rio Grande water stored (pre-San Juan-Chama Project condition--that is, hypothetical), and (3) losses under actual conditions with both Rio Grande and San Juan-Chama waters in storage (present condition). A “control area” is defined so that each of the three conditions can be compared with each other. Although the size of the control area is the same from condition to condition, the composition of the control area changes with and without the lake area condition described below. If El Vado Reservoir is completely iced over, all losses are set to zero.

The control area is an area around and including the lake, generally corresponding to the reservoir area at a high pool level, such as top of the flood-control or conservation pool (**fig. 1**). The control area is composed of five different areas: barren, irrigated, meadow, river, and lake areas. Losses are computed for each type of area as follows:

$$L_{ba} = A_{b} \bullet P_{eff} \bullet AP_{ows}$$

$$L_{ia} = A_i \bullet LR_{ia} \bullet AP_{ows}$$

$$L_{ma} = A_m \bullet LR_{ma} \bullet AP_{ows}$$

$$L_{ra} = A_r \bullet E_t \bullet AP_{ows}$$

$$L_{la} = A_l \bullet E_t \bullet AP_{ows}$$

where:

L_{ba} = barren-area loss, in acre-feet;

A_b = barren area, in acres of surface area;

P_{eff} = effective precipitation, in acre-feet;

L_{ia} = irrigated-area loss, in acre-feet;

A_i = irrigated area, in acres;

LR_{ia} = irrigated-area loss rate, in feet;

AP_{ows} = open water-surface area, in percent;

L_{ma} = meadow-area loss, in acre-feet;

A_m = meadow area, in acres of surface area;

LR_{ma} = meadow-area loss rate, in feet;

L_{ra}	=	river-area loss, in acre-feet;
A_r	=	river area, in acres of surface area;
E_t	=	lake evaporation, in feet;
L_{la}	=	lake-area loss, in acre-feet; and
A_l	=	lake area, in acres of surface area.

See **table 3** for a list of barren-, irrigated-, and meadow-area values used for El Vado Reservoir. **Table 2** provides information for the effective precipitation used for El Vado Reservoir.

Reservoir loss computations (evaporation and precipitation) are based on the end-of-day water surface area (elevation). Irrigated-area and meadow-area loss rates are predefined rates for each type and month. Lake evaporation is pan evaporation (when measured) times a pan evaporation coefficient of 0.70 or is average ambient temperature times a monthly K factor when the pan is frozen and not in use. Open water-surface area percentage is the percentage of lake area that is open or not covered by ice.

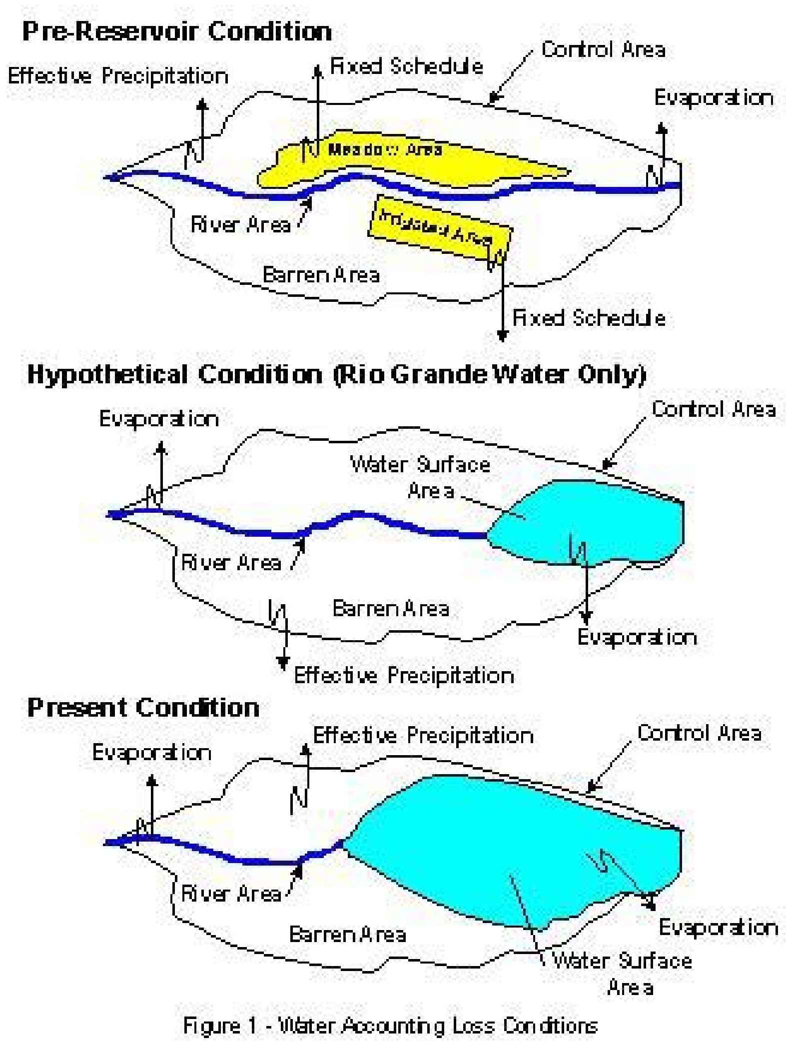

Figure 1. Water accounting loss conditions.

PRE-RESERVOIR CONDITION

The pre-reservoir condition approximates natural losses in the control area without the reservoir. The area of each of the five types of areas is fixed (see **fig. 1**). The loss from the pre-reservoir condition is calculated by the equation:

$$L_{pr} = L_{ba} + L_{ia} + L_{ma} + L_{ra}$$

Where:

L_{pr} = pre-reservoir-condition loss, in acre-feet.

HYPOTHETICAL CONDITION

The hypothetical condition approximates the losses in the control area without San Juan-Chama Project water. The barren area is the control area minus the lake and river areas. The irrigated and meadow areas are assumed to be inundated by the reservoir. The river area is also based on the “Rio Grande only” lake elevation and the relation of river area to lake elevation. The lake area is computed from the reservoir area-capacity table using the hypothetical lake elevation if only Rio Grande water were stored (filling up from the bottom of the lake). The loss from the hypothetical condition is calculated by the equation:

$$L_h = L_{ba} + L_{ra} + L_{la}$$

where:

L_h = hypothetical-condition loss, in acre-feet;

L_{ra} = river-area loss, in acre-feet (based on Rio Grande pool “elevation”); and

L_{la} = lake-area loss, in acre-feet (based on Rio Grande pool “elevation”).

Computation of Rio Grande water content for the hypothetical condition on a given day is not straightforward because the losses are dependent on the content, and the content is dependent on the losses. A reiteration algorithm was developed in the daily programs and utilized in the RiverWare methods code to determine Rio Grande content, water-surface area and losses. The algorithm first estimates Rio Grande content for a given day using the previous day’s Rio Grande content. The Rio Grande losses are computed on the basis of this estimated content. Rio Grande content is then recomputed and compared with the prior value. If they are within 0.5 acre-foot of each other, the most recent Rio Grande content is accepted. If not, an iteration process is initiated using the most recent computed Rio Grande content and re-computing Rio Grande losses until the criterion is met. San Juan-Chama content is computed by subtracting Rio Grande content and, for Corps of Engineers Reservoirs, sediment accumulation from total content.

PRESENT CONDITION

The present condition approximates the current losses in the control area under present reservoir conditions (see **fig. 1**). The barren area is the control area minus the lake and river areas. The irrigated and meadow areas are assumed to be inundated by the reservoir. The river area is computed using the observed lake elevation and a table of lake elevation versus river area. The lake area is computed from the reservoir area-capacity table also using today's observed lake elevation. The loss from the present condition is calculated by the equation:

$$L_p = L_{ba} + L_{ra} + L_{la}$$

where:

L_p = present-condition loss, in acre-feet;

L_{ra} = river area loss, in acre-feet (based on observed elevation); and

L_{la} = lake area loss, in acre-feet (based on observed elevation).

If the reservoir is completely iced over, (i.e., open water = 0%), the losses are set to zero.

NET LOSSES

Net losses, which are applied to the San Juan-Chama and Rio Grande pool, are the losses in excess of natural, pre-reservoir-condition losses. These net losses are computed from the three conditions listed above as follows:

$$NL_{sjc} + NL_{rg} = L_p - L_{pr}$$

and

$$NL_{sjc} = L_p - L_h$$

and

$$NL_{rg} = L_h - L_{pr}$$

where:

NL_{sjc} = net San Juan-Chama loss, in acre-feet; and

NL_{rg} = net Rio Grande loss, in acre-feet.

RECONCILIATION OF LOSSES

The difference in accounting losses that are based on water type and ownership will be different from the losses that are based on the total physical water system. The differences should be handled by the equation:

$$NL_{adj_t} = NL_{phy_t} - NL_{sjc_t} - NL_{rg_t}$$

where:

NL_{adj_t} = daily net loss adjustment, in acre-feet.

$NL_{phy_t} = E_t - P_t$

Table 3. Reservoir areas used in loss calculations

Reservoir	Barren (acres)	Irrigated (acres)	Meadow and town (acres)	River channel (acres)	Lake (acres)
EL VADO					
Pre-reservoir	1420	300	1460	200	N/A
Hypothetical	0 to 3180	(inundated)	(inundated)	0 to 200	0 to 3380
Present	0 to 3180	(inundated)	(inundated)	0 to 200	0 to 3380
ABIQUIU					
Pre-reservoir	7189	N/A	N/A	288	N/A
Hypothetical	0 to 7189	N/A	N/A	0 to 288	0 to 7477
Present	0 to 7189	N/A	N/A	0 to 288	0 to 7477
COCHITI					
Pre-reservoir	6900	40	N/A	840	N/A
Hypothetical	0 to 6900	(inundated)	N/A	0 to 840	0 to 7780
Present	0 to 6900	(inundated)	N/A	0 to 840	0 to 7780
JEMEZ CANYON					
Pre-reservoir	N/A	N/A	N/A	N/A	N/A
Hypothetical	N/A	N/A	N/A	N/A	Water-surface area (varies)
Present	N/A	N/A	N/A	N/A	Water-surface area (varies)
ELEPHANT BUTTE					
Pre-reservoir	N/A	N/A	N/A	N/A	N/A
Hypothetical	N/A	N/A	N/A	N/A	Water-surface area (varies)
Present	N/A	N/A	N/A	N/A	Water-surface area (varies)

ABIQUIU RESERVOIR

OPERATION FOR RIO GRANDE WATER

Abiquiu Dam and Reservoir are operated for flood and sediment control in accordance with conditions and limitations stipulated in the Flood Control Act of 1960 (P.L. 86-645). Reservoir regulation for flood control is also coordinated with the operation of Jemez Canyon, Cochiti, and Galisteo Reservoirs. Abiquiu Reservoir is operated to limit flow in the Rio Chama, insofar as possible, to the downstream channel capacities of 1500-1800 cfs for the reach below Abiquiu Dam; 3000 cfs for the reach below the Rio Chama at Chamita stream gage; and, on the Rio Grande main stem, 10,000 cfs for the reach below the Rio Grande at Otowi stream gage. These channel capacity restrictions result in temporary storage of Rio Grande flood water which is then evacuated as quickly as downstream channel conditions allow, unless and until the conditions imposed by P.L. 86-645 are triggered. Depending on the volume of water from spring runoff, Abiquiu Reservoir has either been able to safely pass inflow without any carryover or has locked in as little as 3500 acre-feet (1994) to as much as 212,000 acre-feet (1987). In addition to carryover flood storage, Rio Grande water has been stored for subsequent release for conservation purposes under special conditions. All other storage is the incidental storage pool. The net Rio Grande loss is distributed among the three Rio Grande Pools on a proportional basis.

Abiquiu Reservoir retains carryover flood storage because no Rio Grande water may be withdrawn from storage under the following conditions: the natural inflow (that is--exclusive of water released from storage upstream) into Cochiti Lake is less than 1500 cfs; at least 212,000 acre-feet of flood-control capacity is available at Cochiti Reservoir; the date is between July 1 and October 31. Rio Grande water that is locked in must remain in storage until the end of the irrigation season (November 1).

In cooperation with, and with the consent of the Rio Grande Compact Commission, Rio Grande water was stored during the 2001 spring runoff for subsequent release for environmental enhancement of the middle Rio Grande valley.

Any other Rio Grande natural inflow to the reservoir during the lock-in period that is not part of the middle valley conservation pool, such as irrigation releases from El Vado Reservoir, is passed through the reservoir. To the extent this water is inadvertently stored, it becomes a portion of the incidental storage.

Unlike at Heron and El Vado Reservoirs, sediment deposition at Abiquiu Reservoir is of sufficient magnitude to affect storage and water accounting computations. The reservoir area is resurveyed every 5 to 7 years. Between surveys, sediment deposition is estimated on the basis of inflow and reservoir storage, and San Juan-Chama contractor storage spaces are reduced as sediment partially displaces them. A detailed description of sediment deposition computations is provided later in this document.

OPERATION FOR SAN JUAN-CHAMA PROJECT WATER

In 1981, P.L. 97-140 authorized the storage of 200,000 acre-feet of San Juan-Chama water in Abiquiu Reservoir. The City of Albuquerque has obtained a storage easement to an elevation of 6220 feet. Real estate interests have not been obtained above elevation 6220 feet to accommodate the full 200,000 acre-feet as authorized. San Juan-Chama capacity is annually reduced because of the estimated sediment deposition. San Juan-Chama storage is held below an elevation of 6220 feet and released as requested by the storage contractors. The San Juan-Chama pool also serves to increase sediment trap efficiency and enhance recreational and fish and wildlife opportunities at the reservoir.

RIO GRANDE AND SAN JUAN-CHAMA STORAGE CALCULATIONS

Sediment in Abiquiu Reservoir was last surveyed in June 1997. The area-capacity table currently being used became effective January 1, 1999. This area-capacity table indicated that San Juan-Chama contractors had 183,881 acre-feet available for water storage at that time, based on the City of Albuquerque land easement at elevation 6220 feet (National Geodetic Vertical Datum of 1929).

SEDIMENT DEPOSITION COMPUTATIONS

The purpose of sediment computations is to estimate the storage capacity lost to sediment deposition between surveys, during which time sediment deposition is estimated on the basis of inflow and reservoir storage. Sediment computation is a multi-step process that results in an estimated volume lost to sediment above and below the operating level of el. 6220 ft. Only the estimated sediment deposition below el. 6220 is accumulated month by month until a new area-capacity table is adopted as a result of a sediment survey.

The total suspended-sediment load for the reservoir is computed using a daily inflow value and coefficient that are based on the time of year. In Abiquiu Reservoir, sediment concentrations vary depending on the time of year. An exponential equation is used to compute suspended-sediment load. This equation is valid for a given range of inflows and takes the following general form:

$$Sed_s = coeff \bullet I^{\exp}$$

where:

Sed_s = suspended-sediment load, in acre-feet;

coeff = coefficient based on inflow;

I = total inflow, in acre-feet; and

exp = exponent based on flow.

The sediment deposited above the permanent pool is determined as follows:

$$P_{fp} = \left[\frac{E_{ws} - E_{tc}}{E_{tc} - E_z}\right] * coeff^{(\exp)}$$

where:

P_{fp} = percentage of sediment in the flood-control pool;
E_{ws} = present water-surface elevation, in feet;
E_{tc} = top of operating pool elevation, in feet (elevation 6220 feet);
E_z = zero storage elevation, in feet (6075 feet); and
coeff = flood-control pool coefficient.

The same sediment unit weight is used for sediment deposited both above and below elevation 6220 feet. The volume of sediment deposited below el. 6220 feet is determined by the equation:

$$Sed_{vpp} = \left(Sed_s \bullet TE \bullet 2{,}000 \bullet 1 - \mathrm{P_{fp}}\right) / D_{pp} \bullet \; 43{,}560$$

where:

Sed_{vpp} = sediment deposited below el. 6220 ft., in acre-feet;
TE = trap efficiency (87 percent for Abiquiu Reservoir); and
D_{pp} = sediment density in permanent (conservation) pool.

SEDIMENT CONTENT EFFECTS

Abiquiu Reservoir storage computations are affected by sediment accumulation carried in from inflows. Once the sediment has been quantified for the pool below elevation of 6220 feet, this accumulated sediment amount, Sed_{vpp}, is applied toward the current Rio Grande content. Under normal conditions when there is no middle valley conservation or carryover pools in storage, all of deposited sediment is applied to the incidental storage. The San Juan-Chama content and Rio Grande content are calculated on the basis of the following equations:

$$S_{sjc_t} = S_{sjc_{t-1}} + I_{sjc_t} - O_{sjc_t} - NL_{sjc_t}$$
$$S_{rg_t} = S_{T_t} - S_{sjc_t} - Sed_{acc}$$

where:

$$Sed_{acc} = Sed_{vpp} + Sed_{vpp(previousday)}$$

Sediment displaces daily some of the total capacity of Abiquiu Reservoir. For accounting purposes, it is important to calculate accurate capacities of the San Juan-Chama contractor pools without sediment estimates during the year but with one sediment adjustment at the end of the year. The sediment calculated by the daily program is only an estimate until the reservoir sediment is officially surveyed and the current reservoir capacity is accurately known.

Total sediment accumulation for the calendar year, estimated by the sediment computation process, that is accounted for in Rio Grande content is adjusted and applied toward San Juan-Chama Project contractor pools at the end of each year at Abiquiu Reservoir. The City of Albuquerque has the largest allocation in the conservation pool. Reductions in San Juan-Chama contractor storage space are applied to other contractors first. Once sediment has replaced these other pools, sediment will begin reducing the City of Albuquerque pool. This arrangement is based on contractor agreements with the City of Albuquerque.

The sediment estimate is also used as a daily tool for water managers in determining any Rio Grande incidental water that is in the reservoir. Under normal circumstances, the permanent pool sediment estimate and San Juan-Chama storage together form the “hold pool”, except under special circumstances where Rio Grande water is held as carryover or middle valley conservation pool. A “hold pool” is calculated daily as follows:

$$S_{hp} = S_{sjc_t} + Sed_{vpp} + S_{rg}$$

where:

S_{hp} = hold pool content, in acre-feet; and

S_{rg} = Rio Grande content (which includes carryover pool, middle valley conservation pool and incidental pool storages), in acre-feet.

Storage in the amount greater than or less than the hold pool is the incidental storage. This hold pool calculation is the authorized storage in U.S. Corps of Engineers (Corps) reservoirs used to determine the amount of incidental Rio Grande in storage.

LOSS CALCULATIONS

Net losses to Rio Grande (natural) and San Juan-Chama storage are calculated for Abiquiu Reservoir using the same method described for El Vado Reservoir. **Table 1** is a tabulation of effective precipitation used for Abiquiu Reservoir. provides data on barren-, irrigated-, and meadow-area values used at Abiquiu Reservoir.

Net Rio Grande losses are distributed pro rata between carryover, middle valley conservation and incidental pools on the basis of percentage of storage. The balance of the difference physical and accounting losses (including sediment) are applied to the incidental pool. Any negative losses (gains) are applied only to the incidental pool.

RECONCILIATION OF LOSSES

The difference in accounting losses that are based on water type and ownership will be different from the losses that are based on the total physical water system. The differences should be handled by the equation:

$$NL_{adj_t} = NL_{phy_t} - NL_{sjc} - NL_{rg_t}$$

where:

NL_{adj_t} = daily net loss adjustment, in acre-feet.

COCHITI RESERVOIR

OPERATION FOR RIO GRANDE WATER

Congress authorized Cochiti Dam in 1960 for flood and sediment control. Operating rules specified in P.L. 86-485 provide that the dam be operated to bypass the maximum possible rate of flow that can be carried in the channel through the middle valley without causing flooding. When inflow exceeds the capacity of the downstream channel, water is retained in the reservoir and held until downstream channel conditions allow for its release, provided that, after July 1, the natural inflow is 1500 cfs or and a minimum of 212,000 acre-feet of storage are available in Cochiti Reservoir to control summer flood flows. Flood storage that is "locked in" is released beginning November 1 (see discussion under carryover storage at Abiquiu Reservoir).

OPERATION FOR SAN JUAN-CHAMA PROJECT WATER

P.L. 88-293 authorized the release of 50,000 acre-feet of San Juan-Chama Project water for the initial filling of a permanent pool of 1200 acres in Cochiti Reservoir and thereafter sufficient water annually to offset evaporation from such areas. A portion of the release of San Juan-Chama Project water is used to offset evaporation loss from the water surface of a small wetland on the Santa Fe River above Cochiti Dam.

RIO GRANDE AND SAN JUAN-CHAMA STORAGE CALCULATIONS

Sediment in Cochiti Reservoir was last surveyed in June 1998, and the current area-capacity table became effective January 1, 1999. This area-capacity table shows that the San Juan-Chama Project permanent recreation pool of 1200 acres of surface area occupies a volume of 49,359 acre-feet at an elevation of 5340.10 feet.

SEDIMENT DEPOSITION COMPUTATIONS

Total suspended-sediment load for Cochiti Reservoir is computed using a daily inflow value and coefficient that are based on the time of year and flow. Sediment concentrations in the reservoir vary depending on the time of year and on inflow. Thunderstorms generally are associated with large sediment concentrations, whereas spring runoff from the high mountains tends to have smaller sediment concentrations. Because of varying flow and sediment-concentration conditions, the year is divided into four periods to compute sediment deposition: October through February, March through May, June, and July through September. For each period, one to three exponential equations are used to compute suspended-sediment load. Each equation is valid for a given range of inflows. The bedload component of total load is based on a single, flow-dependent relation used throughout the year. The suspended-sediment equations take the following general form:

$$Sed_s = coeff \bullet I^{\exp}$$

where:

Sed_s = suspended-sediment load, in acre-feet;

coeff = coefficient based on season and inflow;

I = total inflow, in acre-feet; and

exp = exponent.

The volume of sediment deposited above the permanent pool is determined by the equation:

$$P_{fp} = \left[\frac{E_{ws} - E_{tc}}{E_{tc} - E_z}\right] * coeff^{(\exp)}$$

where:

P_{fp} = percentage of sediment in the flood-control pool;
E_{ws} = present water-surface elevation, in feet;
E_{tc} = top of recreation pool elevation, in feet (elevation 5340.10);
E_z = zero storage elevation, in feet (5247.0); and
coeff = flood-control pool coefficient.

The same sediment unit weight is used for both the flood-control pool and the recreation pool. The volume of sediment deposited in the recreation pool is determined by the equation:

$$Sed_{vpp} = \left(Sed_t \bullet TE \bullet 2000 \bullet 1\text{-} P_{fp}\right) / D_{pp} \bullet 43{,}560$$

where:

Sed_{vpp} = sediment deposited in the conservation pool, in acre-feet;
Sed_t = total load (suspended sediment (Sed_s) and bedload).
TE = trap efficiency (87 percent for Cochiti Reservoir); and
D_{pp} = sediment density in permanent (conservation) pool.

SEDIMENT CONTENT EFFECTS

Once the sediment has been quantified for the recreation pool (below an elevation of 5340.10 feet), this amount, Sed_{vpp}, is applied toward the current Rio Grande content. San Juan-Chama content and Rio Grande content are calculated on the basis of the following equations:

$$S_{sjc_t} = S_{sjc_{t-1}} + I_{sjc_t} - O_{sjc_t} - NL_{sjc_t}$$

$$S_{rg_t} = S_{T_t} - S_{sjc_t} - Sed_{acc}$$

The sediment calculated by the daily program is only an estimate until the reservoir is officially surveyed and the current reservoir capacity is accurately known. The total sediment accumulation for the calendar year, estimated by the sediment computation process, that is accounted for in Rio Grande content is adjusted and applied toward the San Juan-Chama Project recreation pool at the end of each year.

The sediment estimate is also used as a daily tool for water managers in determining any Rio Grande or "incidental" water in the reservoir. For details on Rio Grande carryover, lock-in criteria, incidental storage, and losses, refer to the section titled "Abiquiu Reservoir loss calculations." A "hold pool" is calculated daily as follows:

$$S_{hp} = S_{sjc_t} + Sed_{vpp} + S_{rg}$$

where:

S_{hp} = hold-pool content, in acre-feet; and

S_{rg} = Rio Grande content, in acre-feet.

LOSS CALCULATIONS

Net losses to the Rio Grande (natural) and San Juan-Chama Project water in the recreation pool are calculated for Cochiti Reservoir using the same method described for El Vado Reservoir. The total control area at Cochiti Lake is 7780 acres of surface area. **Table 2** provides information for the effective precipitation used at Cochiti Reservoir. See **table 3** for a list of barren-, irrigated-, and meadow-area values used at Cochiti Reservoir.

RECONCILIATION OF LOSSES

The difference in accounting losses that are based on water type and ownership will be different from the losses that are based on the total physical water system. The differences should be handled by the equation:

$$NL_{adj_t} = NL_{phy_t} - NL_{sjc} - NL_{rg_t}$$

where:

NL_{adj_t} = daily net loss adjustment, in acre-feet.

JEMEZ CANYON RESERVOIR

Jemez Canyon Dam and Reservoir were authorized by the Flood Control Act of 1948 and are operated in tandem with Cochiti Reservoir to control flows through the Middle Rio Grande Valley. During the 1979-2001 period, a sediment-control pool was maintained within that portion of reservoir capacity allocated for sediment deposition. Flood storage, if any, is accumulated atop the sediment-control pool and released as soon as possible thereafter. Jemez Canyon Reservoir is operated to prevent carryover storage of floodwater.

RIO GRANDE AND SAN JUAN-CHAMA STORAGE CALCULATIONS

The capacity of Jemez Canyon Reservoir was last surveyed in June 1998. The area-capacity table currently used became effective January 1, 1999. Approximately 24,425 acre-feet of storage capacity remains in the allocated sediment-control pool.

SEDIMENT DEPOSITION COMPUTATIONS

The total suspended-sediment load for the reservoir is computed using a daily inflow value and coefficient that are valid for a given range of inflow over the entire year. Bedload component is not used. This equation takes the following general form:

$$Sed_s = coeff \bullet I^{\exp}$$

where:

Sed_s = suspended-sediment load, in acre-feet;

coeff = coefficient based on inflow;

I = total inflow, in acre-feet; and

exp = exponent.

The volume of sediment deposited above the sediment-control pool is determined as follows:

$$P_{fp} = \left[\frac{E_{ws} - E_{tc}}{E_{tc} - E_{z}}\right] * coeff^{(\exp)}$$

where:

P_{fp} = percentage of sediment in the flood-control pool;
E_{ws} = present water-surface elevation, in feet;
E_{tc} = top of sediment control-pool elevation, in feet (elevation 5198.13);
E_z = zero storage elevation, in feet (elevation 5155.10); and
coeff = flood-pool coefficient.

The volume of sediment deposited in the sediment-control pool is determined by the equation:

$$Sed_{vpp} = (TE * Sed_t * 2000 * 1\text{-}P_{fp})/D_{pp} * 43560$$

where:

Sed_{vpp} = sediment deposited in the sediment control pool, in acre-feet;
TE = trap efficiency (96.5 percent for Jemez Canyon Reservoir);
Sed_t = total sediment load (suspended plus bedload, if any); and

D_{pp} = density of sediment deposited in sediment-control pool.

SEDIMENT CONTENT EFFECTS

Once sediment has been quantified for the sediment-control pool (below an elevation of 5198.13 feet), this amount, Sed_{vpp}, is applied toward the current Rio Grande content. The San Juan-Chama content and Rio Grande content are calculated on the basis of the following equations:

$$S_{sjc_t} = S_{sjc_{t-1}} + I_{sjc_t} - O_{sjc_t} - NL_{sjc_t}$$

$$S_{rg_t} = S_{T_t} - S_{sjc_t} - Sed_{acc}$$

LOSS CALCULATIONS

Net losses to Rio Grande (natural) and to San Juan-Chama Project water in the sediment-control pool are calculated for Jemez Canyon Reservoir using the same method described for El Vado Reservoir. Effective precipitation **(table 2)** is used to compute net Rio Grande plus San Juan-Chama Project losses. Effective precipitation on the barren area functions as the pre-reservoir condition loss. **Table 3** provides data on barren-, irrigated-, and meadow-area values used at Jemez Canyon Reservoir.

RECONCILIATION OF LOSSES

The difference in accounting losses that are based on water type and ownership will be different from the losses that are based on the total physical water system. The differences should be handled by the equation:

$$NL_{adj_t} = NL_{phy_t} - NL_{sjc_t} - NL_{rg_t}$$

where:

NL_{adj_t} = daily net loss adjustment, in acre-feet.

ELEPHANT BUTTE RESERVOIR

OPERATION FOR RIO GRANDE WATER

Elephant Butte Reservoir is the principal storage facility for the Rio Grande-Chama Project, delivering stored water for downstream use under contract between the USBR and the Elephant Butte Irrigation District in New Mexico and the El Paso County Water Improvement District #1 in Texas. Elephant Butte Reservoir is also operated to ensure that the U.S. 1906 Treaty obligation with Mexico to deliver 60,000 acre-feet per year at the Acequia Madre headgate in Mexico can be met.

OPERATION FOR SAN JUAN-CHAMA PROJECT WATER

In 1981, Congress authorized the Secretary of the Interior to enter into contracts for storage of San Juan-Chama Project water in Elephant Butte Reservoir. P.L. 97-140 provides that the amount of evaporation loss and spill chargeable to San Juan-Chama Project water shall be accounted for under procedures established by the Rio Grande Compact Commission.

San Juan-Chama Project water may also be stored in Elephant Butte Reservoir for recreational purposes. Originally established at 50,000 acre-feet, the recreation pool has substantially diminished in size because of water spill from Elephant Butte Reservoir.

LOSS CALCULATIONS

To account for reservoir losses at Elephant Butte Reservoir, effective precipitation **(table 2)** is used to compute pre-reservoir-condition losses. **Table 3** provides data on barren-, irrigated-, and meadow-area values used at Elephant Butte Reservoir.