Guideline 2019-03

RESERVOIR ACCOUNTING GUIDELINE

Objective

Clarify accounting principles for on-stream and off-stream reservoirs and suggest a standard approach to be used in appropriate circumstances. Unique decree, operational conditions, or water provider policies may result in different approaches from what is suggested herein. Deviations from the suggested guideline that are not pursuant to a decree should be discussed with the Division Engineer.

Guideline

Reservoirs can be categorized as either on-stream or off-stream. The principles described in this guideline apply to on-stream reservoirs and may apply to certain off-stream reservoirs.

On-Stream Reservoir. On-stream reservoirs are those that are located on a natural stream, defined in section 37-87-102, C.R.S. These reservoirs typically receive water continually through streamflow. On-stream reservoir accounting must distinguish the amount of water required to pass through the reservoir from the amount of water legally stored in the reservoir under each water right, on a daily basis. This is because on-stream reservoirs should be operated such that the effect of the reservoir is not noticed by those downstream with senior water rights.

Off-Stream Reservoir. Off-stream reservoirs are those that are located such that a natural stream does not flow through the reservoir. These reservoirs typically fill by diverting water from a natural stream via a ditch or pipeline. Many off-stream reservoirs only need to report the amount of water stored as a diversion record and do not need to provide accounting. In the event an off-stream reservoir stores water pursuant to multiple appropriations or appears to be storing water outside of a decree or without authorization, accounting may be required by the Division Engineer. The requirements of section 37-84-117, C.R.S. do not apply to off-stream reservoirs. The Division Engineer will specify which of the requirements below apply to a particular off-stream reservoir.

General Accounting Data

The following data are needed for on-stream reservoir accounting and for off-stream reservoir accounting when required by the Division Engineer:

a. **Volume released**. This is the measured amount of release made under the dominion and control of the reservoir owner/operator. If releases from the reservoir are not measured, the Division Engineer may refuse to allow water to be stored pursuant to section 37-84-117(3)(b), C.R.S.

b. Volume of water held in storage. The volume of water in storage is determined by a staff gauge (gauge rod or other device) reading to determine the elevation of the water surface and reference to a stage-area-capacity table that is specific to the reservoir and relates the staff gauge reading to volume.[1] The daily staff gauge reading can be performed manually or by using instrumentation, although it should occur at the same time every day to reflect a daily (24 hour) value. Section 37-84-117(2), C.R.S. provides specific requirements for gauge rods. If the amount of water held in storage is not measured with a staff gauge or if the stage-area-capacity table is missing, the Division Engineer may refuse to allow any water to be stored or released from the reservoir pursuant to section 37-84-117(3)(b), C.R.S.

c. Change in storage. Today's volume of water held in storage, at a particular time, subtracted from yesterday's volume of water held in storage, at the same time, will yield yesterday's change in storage amount. (e.g. the 6:00 AM reading from yesterday minus the 6:00 AM reading from today)

d. Evaporation. Daily evaporation rates are estimated by taking the free water surface area, determined from the staff gauge reading and stage-area-capacity table, multiplied by a daily evaporation rate and converted to acre-feet. Daily evaporation rates are commonly estimated from the annual values published in NWS Technical Releases or other methods accepted by the Division Engineer.[2] Pursuant to section 37-84-117(5), C.R.S., on-stream reservoirs are required to make releases for any evaporative losses, less offset covered in Paragraph **f**, when the reservoir is not in-priority to store water, so that all inflow is passed through the reservoir, as if the reservoir did not exist. Aside from an administrative account, a reservoir owner may designate the account from which any evaporative losses are deducted (see **Paragraph h** for more details on an administrative account).

e. Precipitation. When measured precipitation is included in accounting, precipitation is the amount of water that fell on top of the reservoir surface and is calculated as the measured rainfall amount multiplied by the free water surface area of the reservoir.

[1] For on-stream reservoirs, the Division Engineer may restrict the storage volume to that portion of the reservoir above the natural grade.

[2] Operators of off-stream reservoirs may consult with the Division Engineer when daily evaporation estimates do not match field conditions and the resulting Computed Inflow is positive on days when water was not stored. In certain cases, the Division Engineer may approve a change in the calculated evaporation amount to appropriately adjust the Computed Inflow.

f. Evaporation Offset. Section 37-84-117(5), C.R.S. states that "any accretions to the stream flow resulting from the existence of the [on-stream] reservoir and any natural depletions to the stream flow that would have resulted if the reservoir were not in existence" shall be deducted from the evaporation release amount, described in **Paragraph d**. The evaporation offset can be estimated as the amount of precipitation that would have been consumed by evapotranspiration if the reservoir did not exist (effective precipitation). Effective precipitation is estimated as the volume of measured precipitation multiplied by an effective precipitation factor (generally assumed to be 70 percent). The offset to evaporative depletion cannot exceed the daily evaporation rate. After accounting for the evaporation offset, any additional increase in storage is accounted for as water held in storage out-of-priority.

g. Computed Inflow. Inflow is estimated using a mass balance equation. Reservoir measurements are often limited to outflow and stage and other quantities such as seepage and inflow that impact the amount of water in storage may not be available. The most basic version of the mass balance equation is shown below. If additional parameters, such as precipitation, inflow, or seepage are measured at the reservoir, reservoir owners may elect to include them in the mass balance equation. The Computed Inflow is the net sum of all unmeasured inflow and outflow, *R*.

$$Computed\ Inflow\ \ (R) = Change\ in\ Storage + Outflow\ + Evap$$

Please refer to Addendum No.1 for further information on Computed Inflow and the mass balance equation.

h. Administrative Account, sometimes known as Owe-the-river (OTR). As described in the Reservoir Administration Guidelines, water tracked in an administrative account may truly represent water stored out-of-priority or it may reflect the inaccuracies associated with calculating inflow a day late or from multiple measurements that are not precise. Since each water measurement device has some inherent error, the mass balance equation may indicate water inflow fluctuations from day to day. These daily fluctuations typically appear as unmeasured gains or losses from the reservoir and are accounted for in the OTR account. Because the Division Engineer cannot always be certain that calculable increases in storage are in fact out-of-priority diversions and not due to uncertainties or measurement error, the Division Engineer may use discretion and allow the OTR to accumulate up to 1 percent of the total volume of water held in storage (1 percent buffer) before ordering a release pursuant to section 37-92-502(3), C.R.S. Additionally, there are instances when the Division Engineer may order the release of water, such as that captured from storm inflow, within 72 hours even if the volume is less than the 1 percent buffer. However, the 1 percent buffer and the 72-hour allowance do not constitute rules, are not applicable for every reservoir, and may not conflict with the responsibility for reservoir operators to pass through storm water or rainfall that is impounded out-of-priority. For nearly all reservoirs, accounting may not reflect a negative OTR volume, unless special operational or other circumstances warrant consideration and approval by the Division Engineer.

Standard Accounting Practices

i. **Units**. Use acre-feet for volume, cubic feet per second for flow rates, and feet for elevation. Each row or column should be labeled with the appropriate units.

j. **Accounting Period**. The accounting should be set up to show daily operations for the entire year, typically from November 1st to October 31st. The accounting should be set up to show daily operations for the entire year on a single tab, typically from November 1st to October 31st. Days may be arranged in either columns or rows, but this arrangement should be consistent throughout the spreadsheet (either all in columns or all in rows)(please refer to Addendum 2 for an example).

k. **Measurements and Calculations for the Daily Time Period.** Daily surface water elevation readings should occur at the same time every day to reflect a true 24-hour period. Totals that are based on periodic measurements averaged over a 24-hour period (e.g., outflow, precipitation) should coincide with the same 24-hour period as the daily water elevation readings, such as, 8 am to 8 am.

l. **Day-late Accounting**. Reservoir accounting is "day-late" accounting, done in arrears, because we cannot know tomorrow's surface water elevation today. Today, we can subtract yesterday's elevation reading from today's elevation reading to calculate yesterday's change in storage.

m. **Storage Accounts**. The sum of all storage accounts, including the OTR, shall equal the physical amount of water held in storage. All water held in storage shall be accounted for by assigning it to a storage account.

n. **Negative Accounts**. No storage account can be negative. A negative balance suggests that the river "owes the reservoir water" and, with daily call changes, water would likely be stored out-of-priority to gain enough storage to reach a zero or positive balance in the negative account to the detriment of a calling water right.

o. **Free River Storage Account**. Free river[3] means all vested and decreed conditional rights downstream of the reservoir are satisfied and able to divert in-priority because there is no call on the river and water is available for appropriation. Any "free river" water stored in lieu of decreed storage rights is a new appropriation and must be for either (1) amounts in excess of decreed rights already stored, or (2) for new uses not already decreed. In order to store "free river" water, approved accounting is needed (with free river water stored in a specific account) and notice must be provided to the Water Commissioner. Additionally, the Division Engineer will require senior rights to be paper-filled in the same amount as any "free-river" water or junior priority water that is stored before the senior water rights are satisfied.

p. **Measured Seepage.** Unless specifically addressed by a Water Court decree, water lost from a reservoir under or around the dam embankment is considered part of the streamflow available for appropriation downstream of the reservoir because the owner has lost dominion and control of such seepage water. However, water from a system

[3] See additional discussion in Written Instruction 2015-02, Instruction Concerning the Administration of Diversions of Water during Free River.

collecting water inside the dam, which daylights at a discrete measuring point, separate from outlet or spillway releases, may be accounted for as an "accretion to the stream" that can be used to offset evaporative losses in accordance with section 37-84-117(5), C.R.S. and section 37-87-102(4), C.R.S.

q. Bookover. A bookover, as used in this guideline, is an accounting mechanism that replicates storage of inflow to a particular account while simultaneously releasing the same volume from a different account, without physically operating the inlet and outlet works of the reservoir. The result is a paper transfer of water from one account to another. The following limitations apply to bookovers:

- A bookover can only occur when the reservoir is not operating its inlet and outlet works, or when it is physically full and all inflow is passing through the outlet in an uncontrolled manner (e.g., surcharge conditions, or flow-through - when the change in storage is zero).

- Water must be booked-over in-priority or pursuant to an administrative approval at a rate that is the lesser of the available inflow, inlet capacity, or outlet capacity because it replicates the physical operation of the reservoir.

A typical bookover example is when an off-stream reservoir has water in an OTR account and its storage right comes into priority. Rather than divert and release water the OTR can be booked-over into a storage account. A bookover is not allowed if:

- the reservoir is actively storing all of the available inflow without any release, which is simply storage of water.

- the reservoir is actively releasing water; in this scenario, any storable inflow is accounted for as water to storage and the release of water is a release from a storage account.

r. Account Transfers. In addition to bookovers, transfers of volume from one account to another within a reservoir may occur pursuant to decrees, compacts, or otherwise with the approval of the Division Engineer.

Approval
This guideline may only be modified or revoked in writing by the State Engineer.

Approved this 22nd day of November, 2019.

Kevin G. Rein, P.E.
State Engineer/Director

List of Additional Materials:
Addendum 1: Mass Balance Equation
Addendum 2: Example Accounting Sheet
Addendum 3: Example Accounting Workbook

Addendum 1: Mass Balance Equation for Computing Inflow

Mass Balance Equation. Change-in-storage (ΔS) is a function of how much water is stored in and released from a reservoir, as shown in Equation 1.

$$\Delta S = In - Out \qquad [1]$$

The "In" and "Out" variables in the mass balance equation can be expanded to better describe the operations of a reservoir.

$$\Delta S = Inflow_{meas} + Inflow_{unmeas} + Precip - Outflow_{meas} - Outflow_{unmeas} - Evap - Seepage$$

The unmeasured flow terms can be combined to represent the net sum of all unmeasured flows. If seepage or precipitation are unknown, they can also be included in the R term, further reducing the number of variables in the mass balance equation.

$$\Delta S = Inflow_{meas} + Precip - Outflow_{meas} - Evap - Seepage + R$$

or,

$$\Delta S = Inflow_{meas} - Outflow_{meas} - Evap + R$$

Computed Inflow is calculated by using a variation of the Mass Balance Equation.

- When inflow is not measured, the mass balance equation shown above can be re-written so that all inflow is included in the R term. For an on-stream reservoir, the amount of streamflow into the reservoir is often orders of magnitude larger than other unmeasured flows, so R is often assumed to represent a Computed Inflow, as shown below.

  $$\text{Computed Inflow } R = \Delta S - Precip + Outflow_{meas} + Evap + Seepage$$

  It is important to note that in the calculation of Computed Inflow, the Computed Inflow R term really represents the net sum of all unmeasured flows. If Computed Inflow R is calculated to be negative, the net sum of unmeasured outflow exceeds any inflow. In this instance it does not necessarily mean that there was no physical inflow into the reservoir, it only means there was more unmeasured outflow than inflow.

- When inflow is measured, the mass balance equation can be used to solve for the net sum of all unmeasured flows, R. Inflow should be the lesser of (1) the measured inflow, or (2) the measured inflow plus any calculated unmeasured inflow (when R is positive), as shown in Equation 2.

  $$R = \Delta S - Inflow_{meas} - Precip + Outflow_{meas} + Evap + Seepage$$

  $$Inflow = minimum[(Inflow_{meas} + R),\ Inflow_{meas}] \qquad [2]$$

Addendum 2 - Example of an Accounting Sheet

Yellow cells indicate hand entered values. All other values generated by formulas.

Daily elevation data is entered into "Res Elevation" tab & calculated in row 1

Area and Physical Storage (capacity) is taken from "Area & Capacity" tab, calculated automatically in row 7 and row 8

Effective Precip does not exceed total volume of evaporation, nor the total precip

Line #	All Values in Acre-Feet Except Where Noted	Mon 8/1/2018	Tues 8/2/2018	Wed 8/3/2018	Thr 8/4/2018	Fri 8/5/2	Sat 8/6/2018	Sun 8/7/2018
1	Elevation (feet)	51.40	51.36	51.30	51.23	51.17	51.10	51.03
2	Precipitation (in/day)							0.12
3	Weather Station Evap (in/day)							
4	Table Evap (in/day)	0.17	0.17	0.17	0.17	0.17	0.17	0.17
5	Senior River Call (1=yes,0=no)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	Free River (1=yes,0=no)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Area (ac)	877.80	876.72	875.10	873.21	871.59	869.70	867.81
8	Physical Storage	**13264.00**	**13229.00**	**13176.00**	**13115.00**	**13062.00**	**13000.00**	**12938.00**
9	Storage Change	35.00	-35.00	-53.00	-61.00	-53.00	-62.00	-62.00
10	Physical Outflow (cfs)	20.00	45.00	50.00	50.00	50.00	50.00	50.00
11	Physical Outflow	39.67	89.26	99.17	99.17	99.17	99.17	99.17
12	Total Precip	0.00	0.00	0.00	0.00	0.00	0.00	8.68
13	Effective Precip	0.00	0.00	0.00	0.00	0.00	0.00	5.99
14	Volume of Evap	12.32	12.30	12.28	12.25	12.23	12.20	12.18
15	Computed Inflow	86.99	66.56	58.45	50.43	58.40	49.38	40.67
16	Computed Inflow (cfs)	43.86	33.56	29.47	25.42	29.44	24.89	20.51
	OUTFLOW							
17	Primary Account Evap	1.29	1.30	1.30	1.30	1.30	1.30	1.30
18	Secondary Account Evap	11.02	11.01	10.98	10.95	10.93	10.90	10.87
19	Release from Primary Account	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
20	Release from Secondary Account	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
21	Release from OTR Account	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Pass through (auxiliary spillway)	39.67	89.26	99.17	99.17	99.17	99.17	99.17
23	**Total**	51.99	101.56	111.45	111.43	111.40	111.38	111.35

	INFLOW INTO STORAGE							
	Primary Account							
24	Return Flows	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
25	(IN) Exchange 1	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
26	(IN) Exchange 2	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
27	**Total Water Into Primary Account**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Secondary Account							
28	(IN) Exchange 3 - Fully Consumable	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
29	(IN) 2001 Priority Water	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
30	**Total Water Into Sec. Account**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Annual Volumetric: 2001 Priority	10624.82	10624.82	10624.82	10624.82	10624.82	10624.82	10624.82
	OTR Account							
31	(IN) By Exchange or Book-over	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
32	**Total In - Reducing the OTR**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	STORAGE ACCOUNTS							
33	**Total in a Storage Account**	**12934.38**	**12922.08**	**12909.80**	**12897.54**	**12885.31**	**12873.11**	**12869.61**
34	Primary Account	1445.60	1444.30	1443.01	1441.71	1440.41	1439.10	1437.80
35	Secondary Account	11488.78	11477.77	11466.79	11455.84	11444.91	11434.00	11431.81
36	2001 Priority Water	10032.95	10021.95	10010.97	10000.01	9989.08	9978.18	9975.98
37	Fully Consumable	1455.83	1455.83	1455.83	1455.83	1455.83	1455.83	1455.83
	OTR							
38	Today	47.32	-22.70	-40.72	-48.75	-40.77	-49.80	-58.50
39	Cumulative	**329.62**	**306.92**	**266.20**	**217.46**	**176.69**	**126.89**	**68.39**
40	Gate Change:		50 cfs					
41	Time of Change:		12:00 PM					
42	**Comments:**							
43	Formula Changes:							

Sum of all accounts equals physical content (row 33 = row 39 + row 8)

Daily OTR may be negative (row 38) but OTR storage account (row 39) cannot be negative

Addendum 3 - Example of Accounting Workbook

Data should be well organized and categorized by subject on separate worksheets. This keeps the accounting from becoming overly large and unmanageable. The following example shows a workbook with tabs that are likely needed for an on-stream reservoir. Supporting data needed on the "Daily Accounting" tab can be obtained by using formulas to reference other worksheets.

	All Values in Acre-Feet Except Where Noted		Mon 5/7/2018	Tues 5/8/2018	Wed 5/9/2018	Thr 5/10/2018	Fri 5/11/2018	Sat 5/12/2018	Sun 5/13/2018
3	Line #								
4	1	Elevation (feet)	51.40	51.36	51.30	51.23	51.17	51.10	51.03
5	2	Precipitation (in/day)							0.12
6	3	Weather Station Evap (in/day)							
7	4	Table Evap (in/day)	0.17	0.17	0.17	0.17	0.17	0.17	0.17
8	5	Senior River Call (1=yes,0=no)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	6	Free River (1=yes,0=no)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10									
11	7	Area (ac)	877.80	876.72	875.10	873.21	871.59	869.70	867.81
12	8	Physical Storage	**13764.00**	**13729.00**	**13676.00**	**13615.00**	**13562.00**	**13500.00**	**13438.00**
13	9	Storage Change	35.00	-35.00	-53.00	-61.00	-53.00	-62.00	-62.00
14	10	Physical Outflow (cfs)	20.00	45.00	50.00	50.00	50.00	50.00	50.00
15	11	Physical Outflow	39.67	89.26	99.17	99.17	99.17	99.17	99.17
16	12	Total Precip	0.00	0.00	0.00	0.00	0.00	0.00	8.68
17	13	Effective Precip	0.00	0.00	0.00	0.00	0.00	0.00	5.99
18	14	Volume of Evap	12.32	12.30	12.28	12.25	12.23	12.20	12.18
19									
20	15	Computed Inflow	86.99	66.56	58.45	50.43	58.40	49.38	40.67
21	16	Computed Inflow (cfs)	43.86	33.56	29.47	25.42	29.44	24.89	20.51
22									
23									
24		OUTFLOWS							
25	17	Primary Account Evap	1.29	1.30	1.30	1.30	1.30	1.30	1.30
26	18	Secondary Account Evap	11.02	11.01	10.98	10.95	10.93	10.90	10.87
27									
28	19	Release from Primary Account	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
29	20	Release from Secondary Account	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
30	21	Release from OTR Account	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31									
32	22	Pass through (auxillary spillway)	39.67	89.26	99.17	99.17	99.17	99.17	99.17
33									
34	23	Total	51.99	101.56	111.45	111.43	111.40	111.38	111.35

Contacts | Daily Accounting | Calls | Res Elevation | Area & Capacity | Evaporation | Effective Precip | DWR | Sheet 1

Daily accounting sheet (see Addendum No. 2)

Need Contact information for plan administrator, engineer, and attorney. Also need associated case numbers and WDID

Daily staff gauge data can be entered here

Tracking the call can make accounting messy and cumbersome. It is preferable to show the call record on its own sheet

Stage-Area-Capacity table

This worksheet may have a table that distributes annual evap to each month

DWR may ask for a new tab simply labeled "DWR"