Ownership in Storages - SRG

Overview

Description and rationale

Modelling of ownership at nodes is an essential component of modelling water ownership in Source, as it enables ownership to be tracked at nodes in Source models. The rationale for modelling water ownership, and the overall principles, are discussed in Ownership - SRG. This SRG entry deals with those aspects of ownership that apply to water entering, leaving and residing in a reservoir (storage nodes). Requirements are summarised in Table 1. Rules-Based Ordering - SRG describes how owner orders are created, adjusted and released at storage nodes. More information on the storage node is available in Piecewise Linear approach to Reservoir Routing - SRG.

Table 1. Partner user requirements

No	Requirement
1	Ownership of water can be assigned, tracked and reassigned.
1.1	Ability to specify initial ownership of water at each location (all water must be assigned to an owner)
1.2	Ability to specify the transfer of ownership at a location, represented as a node in the river network.
1.3	Borrow and payback is supported, where owners share surpluses to owners that cannot meet their requirements, and can be paid back later.
1.4	In every model component, ownership is conserved when it is not explicitly transferred or exchanged, i.e. the following volume equation holds for each owner ***o***: $Storage_o = Inflow_o - Outflow_o - Diversion_o - Loss_o + Gain_o + Borrowed_o - Lent_o$
2	Ownership tracking works for a range of time steps e.g. sub-daily, daily.
3	Delivery of each owner’s orders may be constrained by their share of inflow and storage volume, and delivery capacity.
4	The equation governing ownership in storages is for an owner ***o***: $Storage_o = Inflow_o - RegulatedRelease_o - Ceded_o - FixedLoss_o - ProportionalLoss_o - InternalSpill_o - ExternalSpill_o + Borrowed_o - Lent_o$
5	Owners can cede (give) water to other owners in a storage.
5.1	The modeller can configure rules that determine when ceding is to take place and how much water to cede from one owner to another owner.
6	Storage losses and gains (evaporation, precipitation, groundwater infiltration) are shared between owners according to user-configured rules.
6.1	Storage losses and gains can be shared proportionally, or according to fixed ratio
6.2	When storage losses and gains are shared proportionally, owners are assigned a share in proportion to the volume of their water in storage.
6.3	When storage losses and gains are shared in a fixed ratio, the modeller configures each owner’s percentage share
7	Owners are assigned fixed shares of storage capacity in which to store their water.
7.1	The modeller can configure each owner’s share of storage capacity.
8	The modeller can configure whether ‘internal spilling’ between owners occurs within a storage.
8.1	When ‘internal spilling’ is configured, owners must transfer the volume of their water that is in excess of their share of storage capacity (the internal spill) to all other owners with ‘airspace’.
8.2	When ‘internal spill’ is transferred from an owner, every other owner receives a share in proportion to their share of storage capacity, but limited by their ‘airspace’.
9	An owner’s share of external spill (release volume in excess of demand) is determined by their share of start of time step storage volume, inflow, regulated release and storage capacity.

10	Storage owner shares can be temporarily overridden and restored later (e.g. Lake Menindee).
10.1	When storage shares are overridden, they are reassigned to a single owner, and all inflows, losses/gains, releases and spills belong to this owner.
10.2	The modeller can configure the conditions under which the override occurs, and the owner to which shares are reassigned.
10.3	When storage shares are restored after an override period, the borrow accounts must be restored to their pre-override balance.
11	Owners are assigned a share of the capacity of each of the storage's outlet paths according to user configured rules.
11.1	Outlet path capacity can be shared proportionally, or according to fixed ratio
11.2	When outlet path capacity is shared proportionally, owners are assigned a share in proportion to the volume of their water in storage.

Scale

The concept of spatial scale in the context of Ownership relates to the fact that it can apply to all or part of the length of a river system. Ownership status can be updated as often as at every model time step, or less often if required.

Principal developer

This version of modelling ownership at storage nodes has been developed by eWater CRC for Source.

Scientific Provenance

Ownership has been modelled in predecessors to Source, such as IQQM and MSM, for many years. The concepts in these models have been updated and enhanced to suit the needs of Source.

Version

Source v3.8.8.

Dependencies

In addition to the dependencies applicable to storage nodes, the minimum requirement is that there should be at least two water users and an Ownership system in the river system being modelled.

Availability/conditions

Automatically included with Source.

Structure & processes

Assumptions

Table 2. Assumptions and Constraints

No	Assumption/Constraint
1	Owners cannot have a negative share of water in storage or transit
2	The sum of each owners' share of flow or storage volume at a model component will equal the total flow or storage volume for the corresponding component.
3	Owners cannot cede more water than the current storage volume.
4	The direction of flow on a wetland link connected to a storage is the direction of net flow volume over the time step.
5	All owners in an ownership system possess a share of the reservoir's storage capacity.

Definitions

Airspace	The difference between the current storage capacity and the volume of water in storage. For an owner: The difference between an owner's current storage capacity and their volume of water in storage.
Ceding	Where an owner gives up water to another owner.
Dead storage	Capacity of a reservoir that is below the minimum operating level and cannot under normal circumstances be released.
External spill	Release from storage in excess of that required to meet downstream requirements.
Full supply level (FSL)	The maximum normal operating level of a reservoir behind a dam. Sometimes the FSL may be set lower than the maximum physical capacity of the dam for management reasons.
Internal spill	Occurs when an owner's volume of water in storage exceeds their current storage capacity and the excess is transferred to the other owners possessing airspace.
Regulated release	The volume of water released to meet downstream requirements.
Spiller	Owner whose share of water in storage exceeds their share of capacity to store it.
Storage	Volume of water stored in the reservoir (dam or weir).
Storage capacity	Volume in storage when the reservoir is at the full supply level. For an owner: The owner's share of the volume in storage when the reservoir is at the full supply level.

Ownership continuity equation

Ownership in reservoirs is governed by the continuity equation, in which each owner's share of water is conserved. Ownership of water is changed only in the following set of cases:

- Water is ceded to other owners according to rules configured by the modeller.
- An owner does not have sufficient storage capacity to hold its water, so it is internally spilled to other owners. (The modeller may opt to disable this process where it is not required).
- Water is borrowed or lent to other owners so that demand can be met. Borrow accounts are used to track this lending, so that water is later paid back either at the nominated payback storage, or via the resource assessment process (as described in Borrow and Payback - SRG).

Ownership can also be temporarily suspended. When this occurs, all water in the reservoir is assigned to a single owner, and the borrow and payback processes are turned off.

An owner’s volume of water in storage is adjusted for their share of inflows, regulated releases, external and internal spills, lateral losses and gains, and flows along wetland links. Inflows may be from upstream or via wetland links. Regulated release ownership is determined by each owner’s downstream order.

Lateral losses and gains include rainfall, evaporation and groundwater infiltration. These fluxes are categorised into those that are shared in proportion to the share of water stored, or according to fixed ratio. The user configures which of the lateral fluxes fall into each category (fixed/proportional). Wetland link flows are treated as fixed losses (see Ownership in Wetlands - SRG for more information).

Therefore, for an owner, *i*, the continuity equation gives for a time step:

Equation 1	$V_2^i = V_1^i + I_i - C_i - P_i - F_i - IS_i - ES_i + B_i - R_i$

where:

V_2^i - Owner 's volume of water in the reservoir this time step.

V_1^i - Owner 's volume of water in the reservoir last time step.

I_i - Volume of inflow this time step belonging to owner *i*.

C_i - Net volume of water ceded by owner *i* this time step to all other owners, negative if this owner has ceded less water to other owners than received.

P_i - Proportional loss attributed to owner *i*, negative if a gain.

F_i - Fixed loss attributed to owner *i*, negative if a gain.

IS_i - Net internal spill of owner *i*, negative if spill into owner’s share.

ES_i - External spill for owner *i*.

B_i - Total borrowed from other owners by owner *i*, negative if the owner is lending to other owners.

R_i - Volume of regulated water released this time step for owner *i*.

This methodology uses an implicit (backward) Eulerian numerical scheme which implies that fluxes that are a function of the state of the reservoir are a function of the end of time step value (V_2).

The modeller may disable internal spills, so this element may be left out of the equation.

Each owner’s inflow and last time step storage is known at the start of the reservoir ownership calculations. Shares or functions configured by the modeller determine owner fixed losses and volumes ceded or received (noting that owners cannot cede more than the current storage volume). The remaining parts of the equation to be calculated are the owner’s borrow, internal spill (where relevant), external spill and proportional loss.

Borrow and payback

Owners with insufficient water in the reservoir to meet their release requirements can borrow it from other owners with surplus water. Payback occurs in a reservoir only when it has been configured as a ‘payback storage’, i.e. it:

- has a local borrow and payback system that tracks borrow in the reservoir

or

- is the ‘reconciliation’ storage for the ‘global’ borrow and payback system used to track borrow within the ownership system governing the river/section of river the reservoir forms part of.

When the reservoir is a ‘payback storage’, owners with water surplus to their release requirements will pay back any water they borrowed earlier by reassigning part or all of the surplus to their creditor(s).

> **Note:** Borrow and payback calculations do not occur when ownership is suspended.

Borrow calculations

Knowing that when an owner draws its share of the storage down to zero, its share of the proportional losses will also be zero, for each owner, *i*, the maximum volume of water it can release this time step without relying on borrowing (by setting $B_i = 0$) can be calculated:

Equation 2	$R^i_{max} = V^i_1 + I_i - C_i - F_i$

If the reservoir is empty, this equation is modified to account for proportional gains (such as rainfall) that could be released, or that have dried up the reservoir over the period considered:

Equation 3	$R^i_{max} = V^i_1 + I_i - C_i - F_i - r_i P$

where:

> r_i - Owner i's ratio share of the reservoir's storage capacity.
>
> ***P*** - Total proportional loss, negative if a gain.

From this, surplus and deficit release capacities can be calculated for each owner:

Equation 4	$Deficit_i = max(R_i - R^i_{max}, 0)$

Equation 5	$Surplus_i = max(R^i_{max} - R_i, 0)$

Using the borrow method described in Borrow and Payback - SRG B_i for each owner can be calculated. Any owner that had to borrow will have $V^i_2 = 0$.

$\boldsymbol{B_i = Borrowed_i - Lent_i}$

> **Note:** Borrow account balances are updated for borrowing in storages, except when ownership is suspended (see section on *Suspension of Ownership*).

Payback calculations

If this reservoir is a payback storage, shares of storage are adjusted as owners with the capacity to do it, pay back water that they borrowed earlier. The surplus release capacities are re-evaluated but this time water already lent is considered:

Equation 6	$Surplus_i = max(R^i_{max} + B_i - R_i, 0)$

Equation (6) returns a value of zero for owners that had to borrow water. It is only necessary to calculate the repayment for owners with a positive surplus that have previously borrowed from other owners ($Surplus_i > 0$, *|BPSystem.NetBorrow(i, OtherOwner)| > 0*). Borrow and Payback - SRG describes distribution systems and priority levels.

Payback is done at each priority level in order from highest to lowest:

At a given priority level, *pl*, for each owner, *i*, that has a $Surplus_i > 0$, the steps are:

1. Accumulate amount the owner owes other owners at the priority level:

Equation 7	$CanPayback(pl, i) = \sum_{OtherOwner} BPSystem.NetBorrow(i, OtherOwner)$

2. If the owner has borrowed from any other at the priority level (*(CanPayback(pl, i) > 0)*):
   a. Calculate the ratio to limit the owner's payback to their current ability to repay:

Equation 8	$PaybackRatio_i = min\left(\frac{Surplus_i}{CanPayback(pl,i)}, 1\right)$

b. For every other owner *OtherOwner* that shares with owner *i* at the priority level:

i. Calculate the payback to the other owner using the ratio above

Equation 9	$PaybackRatio_i = min\left(\frac{Surplus_i}{CanPayback(pl,i)}, 1\right.$

ii. Update the borrow record for the payback to the other owner

Equation 10	$BPSystem.NetBorrow(i, OtherOwner) = BPSystem.NetBorrow(i, OtherOwner) - Payback(i, Othe$

Equation 11	$BPSystem.NetBorrow(OtherOwner, i) = BPSystem.NetBorrow(OtherOwner, i) + Payback(i, Othe$

iii. Adjust current time step borrow totals for the payback:

Equation 12	$B_{OtherOwner} = B_{OtherOwner} + Payback(i, OtherOwne$

Equation 13	$B_i = B_i - Payback(i, OtherOwner, pl)$

iv. Update the surplus remaining to be shared at the next priority level down:

Equation 14	$Surplus_i = Surplus_i - Payback(i, OtherOwne$

Forfeiture of credit

If a reservoir is a payback storage, a check is made to ensure that no owner's credit owing to them exceeds their capacity to store it. If any owner has more water owed to them than they have remaining airspace, the excess is forfeited back to the debtors in order of priority. This methodology is similar to that used for calculating payback, but in this case the forfeits run in the opposite direction to the repayments.

Each owner's current airspace can be calculated as:

Equation 15	$Airspace_i = max(V^i_{max} - V^i_2, 0)$

The total credit owed to an owner *i* is:

Equation 16	$TotalCredit_i = \sum max(-BPSystem.NetBorrow(OtherOwner, i), 0)$

The maximum volume each owner will be required to forfeit:

Equation 17	$MaxForfeit_i = max(TotalCredit_i - Airspace_i, 0)$

If any owner's value of $MaxForfeit_i$ is greater than zero, there is credit that must be forfeited.

The process to forfeit credit is done at each priority level, in order from highest to lowest:

At a priority level, for each 'creditor' owner *i* that has a $MaxForfeit_i > 0$, the steps are:

1. Accumulate the amount owed to the creditor by other owners sharing at the priority level:

Equation 18	$Owed_i = \sum_{\text{other owner}} -BPSystem.NetBorrow(OtherOwner, i)$

2. If the creditor has an amount owing at this priority level ($Owed_i > 0$):
    a. Calculate the amount of credit forfeited to each other owner at the priority level - this is proportional to the other owner's share of the total owed to this owner at the priority level:

Equation 19	$Forgo^i_{OtherOwner} = \frac{-BPSystem.NetBorrow(OtherOwner, i)}{Owed_i} \times min(Owed_i, MaxForfei$

    b. Adjust the borrow record for the creditor and their debtors for the amount forgone:

Equation 20	$BPSystem.NetBorrow(i, OtherOwner) = BPSystem.NetBorrow(i, OtherOwner) + Forgo^i_{OtherO}$
Equation 21	$PSystem.NetBorrow(OtherOwner, i) = BPSystem.NetBorrow(OtherOwner, i) - Forgo^i_{OtherO}$

    c. Update the amount left to forfeit at the next priority level down:

Equation 22	$MaxForfeit_i = MaxForfeit_i - \sum_{OtherOwner} Forgo^i_{OtherOwner}$

Spill calculations

Each owner is entitled to use a fixed proportion** of the storage capacity of a reservoir (r_i) which means that at any time its storage cannot exceed:

> ** Owners that have a share of the reservoir which floats on top of the other owners will have to be dealt with later. If an owner doesn't have any storage capacity ($r_i = 0$) then its water will internally spill to those owners that do.

Equation 23	$V^i_{max} = r_i \times max(V_{max}, V_2)$

where:

V^i_{max} - Owner *i*'s maximum allowed volume of water in the reservoir this time step.

r_i - Owner *i*'s ratio share of reservoir storage capacity.

V_{max} - Storage capacity of reservoir.

V_2 - Storage volume of reservoir this time step.

The maximum function in equation (23) is used to cover the cases where the reservoir is surcharged. If the reservoir is currently subject to a pre-release (A pre-release can be releases made for flood mitigation or in the case of Dartmouth Dam, for example, those made through the power station when the storage is above a defined target level.) then the storage capacity is considered to be the current storage volume and equation (23) becomes:

Equation 24	$V^i_{max} = r_i \times V_2$

For any owner, i, to be spilling $V^i_2 = V^i_{max}$ otherwise the owner would still possess airspace and would not be spilling, and also the current storage volume cannot be greater than the maximum by definition.

Identifying spilling owners

Before each owner's share of spills can be determined, it is necessary to determine which owners will spill. Where the spill calculation returns a negative value, owners can receive internal spill, while a positive value indicates that the owner is spilling (has filled their storage share).

Case when there is net proportional loss (P 0)

This case applies if there is a net proportional loss from a non-empty reservoir, or on the unusual case of an empty reservoir that spills over the time step due to net proportional gain. Equation (1) is rearranged to give an expression for the volume of water that can spill (internally and externally) from an owner's capacity share:

Equation 25

$$Spill_i = V_1^i - V_{max}^i + I_i - C_i - \frac{V_{max}^i}{V_2} P - F_i - R_i + B_i$$

Case when there is net proportional gain (P < 0)

Where there is a net gain of fluxes that are proportionally shared, allowance is made for the fact that some owners may have their share of the storage filled and the excess has to be given to the other owners. Firstly, where each owner's storage would be without the gain is estimated, making sure that this estimate does not exceed its current storage capacity:

Equation 26

$$V_{est}^j = min\left(max\left(V_1^i + I_i - C_i - F_i - R_i + B_i, 0\right), V_{max}^i\right)$$

where:

> The superscript j denotes owners with capacity to receive spills.

Proportional gain P is distributed in an iterative process. Initially the proportional gain remaining to be distributed (P_{rem}) equals the total P, and every owner's spill $Spill_i$ is zero. P_{rem} is distributed until there are no more owners that will spill. This process is outlined below:

1. A total of the estimated unassisted storage volumes is calculated:

$$V_{est} = \sum V_{est}^j \left[Spill_j \leq 0\right]$$

> **Note:** This is using the notation suggested by Knuth (1992 [http://arxiv.org/abs/math/9205211v1]). Essentially it's saying that the summation is for all of the terms where the conditions in the square brackets are true. So [$Spill_j$ 0] indicates that we want the summation of V^j_{est} for all j where $Spill_i$ is less than or equal to zero.

2. For each owner not already identified as spilling ($Spill_j$ 0) we calculate an initial estimate of their spill volume totals:

Equation 27

$$Spill_j = V_1^j - V_{max}^j + I_j - C_j - \max\left(\frac{V_{est}^j}{V_{est}} P_{rem}, \frac{V_{max}^j}{V_2} P\right) - F_j - R_j + B_j$$

3. If an owner is discovered to be spilling ($Spill_j > 0$), the remaining proportional gain is updated:

Equation 28

$$P_{rem} = min\left(0, P_{rem} - \frac{V_{max}^j}{V_2} P\right)$$

4. And a final estimate of total spill calculated:

Equation 29	$$Spill_j = V_1^j - V_{max}^j + I_j - C_j - \frac{V_{max}^j}{V_2} P - F_j - R_j + B_j$$

5. If during this pass any owners are discovered to be spilling then it is necessary to return to equation (27) and keep repeating the process until no more spilling owners are discovered.

When the process is finished equation (30) is evaluated for those owners found to be not spilling.

Calculating internal and external spill shares

The calculations in previous sections established which owners are spillers when proportional gains and losses are taken into account. The next step is to determine the internal (between owners) and external (leaving the reservoir) components of the spill. Based on the calculations in the previous sections the total spill is:

Equation 30	$$TotalSpill = \sum Spill_i \; [Spill_i > 0]$$

The total external spill is the total outflow *O* minus the total release for all owners:

Equation 31	$$ExternalSpill = O - \sum R_i$$

Case where internal spills are disabled

If internal spill is disabled the internal spill volume is zero ($IS_i = 0$). The ownership of the external spills is set based on how much each owner would spill in total if internal spill was operating:

Equation 32	$$ES_i = max\left(\frac{Spill_i}{TotalSpill} ExternalSpill, 0\right)$$

Case where internal spills are enabled

When internal spill is active, the total internal spill is the difference between the total and external spills:

Equation 33	$$InternalSpill = Max(TotalSpill - ExternalSpill, 0)$$

The ratio of external to total spill is:

Equation 34	$$rExternal = \min\left(\frac{ExternalSpill}{TotalSpill}, 1\right)$$

So, for an owner *i*, the external spill is:

Equation 35	$$ES_i = max(rExternal \times Spill_i, 0)$$

For spilling owners, internal spill is the difference between their total and external spills. Internal spill is zero if the owner is not spilling:

Equation 36	$$IS_i = max(Spill_i - ES_i, 0)$$

Water spills to those owners with airspace in proportion to their share of the storage capacity, *r*. Only owners, *j*, with capacity to receive spills are considered, so the fraction of internal spills an owner is entitled to is:

Equation 37	$$spillFraction_i = \begin{cases} r_i / \sum_{j \in non\ spilling\ owners} r_j\ , & Spill_i < 0 \\ 0, & Spill_i \geq 0 \end{cases}$$

The calculation is complicated by the fact some of the receiving owners may fill their share before the entire internal spill is transferred. To handle this we use an iterative approach where the spill is shared until one of the receiving owners is full and the weights from equation (37) are recalculated and the process repeated until there is no unaccounted for internal spill. Firstly a capacity limit is calculated for each owner that can receive internal spill.

Equation 38	$$cap_i = \begin{cases} \dfrac{-Spill_i}{spillFraction_i \times InternalSpill}, & Spill_i < 0 \\ +Inf, & Spill_i \geq 0 \end{cases}$$

Finding the smallest value of cap_i (*Mincap*) making sure that it is no more than 1,

Equation 39	$$MinCap = min(\,cap_1, ..., cap_i,\ 1\,)$$

The incremental internal spill for every owner, *i*, is calculated as:

Equation 40	$$IncSpill_i = \begin{cases} min(MinCap \times spillFraction_i \times InternalSpill, -Spill_i), & Spill_i < 0 \\ 0, & Spill_i \geq 0 \end{cases}$$

The total internal spill is then updated to represent the amount remaining:

Equation 41	$$InternalSpill = InternalSpill - \sum IncSpill_i$$

and each owner's share of internal spills is also updated to:

Equation 42	$$IS_i = \begin{cases} IS_i - IncSpill_i, & Spill_i < 0 \\ IS_i, & Spill_i \geq 0 \end{cases}$$

The values of $Spill_i$ are updated:

Equation 43	$$Spill_i = \begin{cases} Spill_i + IncSpill_i, & Spill_i < 0 \\ Spill_i, & Spill_i \geq 0 \end{cases}$$

The process from equation (37) to equation (43) is repeated until *InternalSpill* approaches zero. Once this occurs the values of Es_i and IS_i will also be known for all owners where $Spill_j$ *0* the value of V^i_2 will be V^i_{max}.

Proportional Loss Sharing

If internal spill is active, each spilling owner, *k*, is required to meet a fixed part of the proportionally shared lateral flows:

Equation 44	$$P_k = \frac{V_{max}^k}{V_2} P \, [Spill_k > 0]$$

The proportional loss remaining to be shared by non-spilling owners is then:

Equation 45	$$P_{rem} = P - \sum P_k \, [Spill_k > 0]$$

This remaining proportional loss is shared between each non-spilling owner according to their share of non-spilling owner storage:

1. First, each non-spilling owner *j*'s storage is estimated using the ownership continuity equation, without proportional loss:

Equation 46	$$V_{est}^j = V_1^j + I_j - C_j - F_j - IS_j - ES_j + B_j - R_j$$

2. The estimated total storage of non-spilling owners (without proportional loss considered) is:

Equation 47	$$NoSpillV_{est} = \sum V_{est}^j \, [Spill_j \leq 0]$$

3. Hence, the proportional loss for each non-spilling owner *j* is then:

Equation 48	$$P_j = \frac{V_{est}^j}{NoSpillV_{est}} P_{rem}$$

A revised (final) storage volume is then calculated for all owners from:

Equation 49	$$V_2^j = V_{est}^j - P_j$$

To determine the evaporation, rainfall and groundwater infiltration components of proportional losses for each owner, the owner share of proportional loss is applied to totals for each proportional flux type:

Equation 50	$$ProportionalFlux_{type}^i = \frac{P_i}{P} \times ProportionalFlux_{type}$$

Suspension of Ownership

Ownership in a reservoir may be temporarily suspended. This occurs when a storage override function configured by the modeller returns a value of "true". At this point, the owners' storage shares are saved, and borrow account balance updating is turned off.

When the override function returns a value of "false" following on from one of "true", the ownership system is restored to the state it was in before ownership was suspended. This means that the owners' storage shares are restored to the values saved before ownership was suspended, and borrow account balance updating is turned back on.

The current share of water in storage for each owner is saved when the result of the override function transitions from "false" to "true", which is when the suspension is activated (If the reservoir is empty then $V = 0$ and $Share_i = r_i$.):

Equation 51	$$Share_i = \frac{V^i}{V}$$

where:

> r_i - Owner *i*'s ratio share of the reservoir's storage capacity.
>
> V^i - Owner *i*'s volume of water in the reservoir.
>
> ***V*** - Total volume stored in the reservoir.

When ownership is suspended, all water is temporarily reassigned to a single owner *s*. The storages are reset:

Equation 52	$$V^i = \begin{cases} V, & i = s \\ 0, & i \neq s \end{cases}$$

The owners' shares of the storage capacity are overridden:

Equation 53	$$r_i = \begin{cases} 1, & i = s \\ 0, & i \neq s \end{cases}$$

While the suspension is in place the normal calculations are followed, and borrowing can still occur, but any borrowing is not recorded and it is not paid back.

When the result of the override function transitions from "true" to "false", that is the suspension is deactivated, each owner's share of water in storage is reset to represent what it was before the suspension started:

$V^i = Share_i \times V$

The owners' shares of the storage capacity (r_i) are restored to the values they were before the suspension started.

Outlet Path Ownership

Determining capacity

Outlet capacity is described by a modeller configured minimum and maximum possible release at each storage level in a piecewise relationship. The capacities of outlets on the same outlet path are combined to determine the minimum and maximum release for an outlet path at each storage volume in the relationship. The slopes and intervals of these outlet path relationships are used to calculate the release range for any storage volume, which are adjusted to take into account spill (the minimum release) at the storage level on all other outlet paths. There may be multiple outlet paths for the same storage, with differing priorities. Hence outlet path release ranges are adjusted in each time step for releases on higher priority outlet paths. Further information on outlet path minimum and maximum release calculations is available in Piecewise Linear approach to Reservoir Routing - SRG.

Sharing release capacity

Shares of outlet path capacity are input by the modeller. Outlet path capacity is shared either in proportion to the owner's share of last time step's storage volume (V_1^i/V_1), or as a fixed ratio.

As ownership is calculated after the physical reservoir model has been run the volume of water that was released from the reservoir in the current model time step is known:

Equation 54	$$R = \sum R_p$$

where:

> ***R*** - The total volume released from the reservoir this time step.
>
> R_p - The total volume released from the reservoir this time step down outlet path *p*.

The total order on each outlet path is the sum of orders on that path for all owners:

Equation 55

$$Orders_p = \sum Order_i^p$$

Case where outlet path release total order

Where any path's outflow equals or exceeds the total orders on that path (*R_p > 0)* then the regulated releases do not have to be restricted and each owner's release can be set equal to their order:

Equation 56

$$R_i^p = Order_i^p$$

Case where outlet path release < total order

If the outflow down a path is less than the orders on that path then there is a restriction and the water considered to have been released for each owner has to be scaled back. For each owner, their share of the release capacity is calculated as follows:

Equation 57

$$ReleaseCap_i^p = \begin{cases} Share_i^p \times R_p, & If\ fixed\ ratio\ sharing \\ \frac{V_1^i}{V_1} \times R_p, & If\ proportional\ and\ V_1 > 0 \\ r_i \times R_p, & If\ proportional\ and\ V_1 = 0 \end{cases}$$

From this, surplus and deficit release capacities can be calculated for each owner:

Equation 58

$$Deficit_i = max(Orders_i^p - ReleaseCap_i^p, 0)$$

Equation 59

$$Surplus_i = max(ReleaseCap_i^p - Orders_i^p, 0)$$

If any owner possesses a surplus, the borrow method described in Borrow and Payback - SRG is used to calculate B_i for each owner with a deficit. The records of borrowing and payback are not updated for these transactions

Equation 60

$$B_i = Borrowed_i - Lent_i$$

The regulated flow going down this path can then be set as:

Equation 61

$$R_i^p = ReleaseCap_i^p + B_i$$

Once this is done for all the outlet paths, the total regulated release for each owner is:

Equation 62

$$R_i = \sum R_i^p$$

> **Note:** When ownership is suspended, the 'override owner' is assigned 100% share of outlet path capacity. If there are any orders for other owners at this time, the other owners may still borrow capacity in order to make a release. This situation is unlikely though, as the ordering system should detect that the other owners have no storage share and send their orders elsewhere (where possible).

Data

Input data

Details on input data requirements are provided in the Source User Guide.

Parameters or settings

Input parameters and setting are summarised in Tables 3 and 4, below.

Table 3. Storage Ownership Parameters

Parameter Name	Parameter Description	Unit type	No. of values	Allowable values & validation rules	Default Value(s)
Ownership system	Name of the storage's ownership system	n/a	1	An existing ownership system for the scenario.	Default ownership system
Enable internal spilling	Indicates whether owners will transfer water to other owners when they have insufficient capacity to store their water.	n/a	1	'Yes' or 'No'	'Yes'
Storage sharing table: Owner	An owner in the storage's ownership system.	n/a	Number of owners in o.s.	Read only	Each owner in the storage's o.s.
Storage sharing table: Capacity share	The owners % share of storage capacity.	%	1 per owner	Real 0-100%	Equal share of 100 per owner.
Storage sharing table: Capacity	The owner's storage capacity.	volume	1 per owner	Read only	*share* x Storage Capacity
Storage sharing table: Initial storage share	The owner's % share of initial storage.	%	1 per owner	Real 0-100%	Equal share of 100 per owner.
Storage sharing table: Initial storage	The owner's initial storage.	volume	1 per owner	Read only	*share* x Initial storage
Ceding table: From owner	An owner that will cede a volume of water dictated by the ceding function to the 'To owner'	n/a	0 or more	An owner in the storage's ownership system.	None
Ceding table: To owner	An owner that will receive a volume of water dictated by the ceding function from the 'From owner'	n/a	1 per 'From owner'	An owner in the storage's ownership system.	None
Ceding table: Ceding function	Function that determines the volume of water the 'from' owner will cede to the 'to' owner each time step.	volume	1		None
Rainfall and evaporation sharing method	Indicates how rainfall and evaporation are shared.	n/a	1	'Fixed Ratio' or 'Proportional'	'Proportional'
Groundwater sharing method	Indicates how groundwater infiltration is shared.	n/a	1	'Fixed Ratio' or 'Proportional'	'Proportional'
Override owner	An owner that will receive 100% ownership of a storage, its inflows, losses/gains & releases when the override function returns true.	n/a	1	An owner in the storage's ownership system	None
Override function	function that determines when owner shares are to be overridden (when true)	n/a	1	Must return true or false value.	'False'

Table 4 — Storage Outlet Path Ownership Parameters

Parameter Name	Parameter Description	Unit type	No. of values	Allowable values & validation rules	Default Value(s)
Outlet path	Name of a storage outlet path	n/a	1 per outlet path	Read only	Name of configured outlet path
Outlet path: Capacity sharing method	Indicates whether the outlet path's capacity will be shared in fixed ratio or in proportion to each owner's storage.	n/a	1 per outlet path	'Fixed Ratio' or 'Proportional'	'Proportional'
Outlet path capacity sharing table: Owner	An owner in the storage's ownership system	n/a	1 per owner in o. s. *	Read only	Each owner in the storage's o. s. *
Outlet path capacity sharing table: Share	Owner's percentage share of outlet path capacity.	%	1 per owner & outlet path	Owner percentages for each outlet must add up to 100%	Equal share of 100 per owner.

* **Note**: The initials o.s. refer to the current storage's ownership system.

Output data

Recorded variables are summarised in Tables 5 and 6, below.

Table 5. Recorded variables: Storage ownership

Model element	Parameter	Units	Variable/calculation	Freq.	Display format
Storage + owner	Upstream inflow rate	Volume /time	I_i/dt	Time step	Displayed as: Graph, Table, Statistics (min, max, average over the modelled time period)
	Upstream inflow volume	volume	I_i		
	Storage volume	volume	$V^i{}_2$		
	Ownership overridden	0 or >0	No variable. Any value >0 indicates override.		
	Evaporation volume	volume	P_i/P or fixed owner% × Storage evaporation volume		
	Rainfall volume	volume	P_i/P or fixed owner% × Storage rainfall volume		
	Infiltration volume	volume	P_i/P or fixed owner% × Storage infiltration volume		
	Wetland flow volume	volume	See Wetlands SRG		
	Wetland flow rate	volume /time	See Wetlands SRG		
	Ceded volume	volume	No variable		
	Internal spill volume	volume	IS_i		
	External spill rate	volume /time	ES_i/dt		
	External spill volume	volume	Es_i		
	Release rate	volume /time	R_i/dt		
	Release volume	volume	R_i		

Table 6. Recorded variables: Storage outlet path ownership

Model element	Parameter	Units	Variable /calculation	Freq.	Display format

Storage + outlet path + owner	Release rate	volume /time	R^i_p/dt	Time step	Displayed as: Graph, Table, Statistics (min, max, average over the modelled time period)
	Release volume	volume	R^i_p		